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RADIOIODINE STUDIES FOLLOWING THE TRANSIENT NUCLEAR TEST (TNT) OF A KIWI REACTOR

by
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ABSTRACT

In conjunction with the Transient Nuclear Test of a Kiwi reactor, on January 12, 1965, hay contamination and controlled dairy cow ingestion studies for radioiodines were conducted. The studies were designed to simulate the maximum possible radioiodine uptake by dairy cows under winter dairy farming conditions, where radioiodines enter the cows via ingested, contaminated hay. The kinetics of the secretion of radioiodines in milk under the conditions of this experiment were determined. Peak values of 830 pCi/liter for ^{133}I and 150 pCi/liter for ^{131}I were observed in the milk of individual cows. For ^{131}I the effective half-life in the milk of Group I cows was found to be 5.7 days, whereas for Group II it was 2.9 days. Air sampling results indicated that the contaminant ingested by Group I cows was less gaseous in nature than was the contaminant for Group II cows.

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I. INTRODUCTION

The Kiwi Transient Nuclear Test (TNT) was conducted at 1058 hours PST on January 12, 1965, at Test Cell C, Nuclear Rocket Development Station, Jackass Flats, Nevada. The experiment consisted of a rotation of the control drums from a Kiwi reactor at a rate approximately 90 times faster than the maximum possible operational rate and was designed to simulate a maximum possible transient of the Kiwi nuclear reactor. Predictions of the probable production and release of mixed fission products made before the test by the Los Alamos Scientific Laboratory indicated that radioiodine studies at distances close to the release point had a high probability of yielding significant scientific results. For a more complete description of the test itself and of environmental measurements of the effluent made following TNT the reader is referred to References 1 and 2.

The present studies were designed in part to obtain data to relate certain transport properties of radioiodines from the TNT effluent to similar properties of the effluent which was accidentally released following the Pike underground nuclear test. Results obtained in our experiments following Pike have previously been reported.[3] One of the significant findings of our Pike study was the measurement of ^{131}I levels in the milk of dairy cows eating only grain and contaminated hay. The peak levels were a factor of approximately six lower than the measured peak levels of ^{131}I in the milk of different dairy cows eating contaminated fresh green forage at the same location. In addition, the apparent effective half-life of ^{131}I observed in the milk of dairy cows eating fresh green forage appeared to differ from the effective half-life of ^{131}I observed in the milk of dairy cows eating only hay and grain.

Since TNT occurred in winter when there was no fresh green forage available, the experimental design was limited to the use of hay as a sampler for fallout radioiodines. The study was designed and conducted to simulate the maximum possible uptake of radioiodines which could result from winter dairy farming practices where radioiodines enter dairy cows via contaminated hay.

A total assessment of radioiodine uptake by dairy cows must include measurement of air uptake, uptake from ingestion of contaminated fresh green forage, uptake from ingestion of contaminated hay and/or grain, and uptake from contaminated water. This study design allows the measurement of only one of the possible uptakes (hay). Subsequent studies will be designed to assess other possible uptake routes.

The experiment was designed around the following specific objectives:

1. To determine the amount of radioiodines deposited on stacked, baled alfalfa hay and on loosely piled alfalfa hay at the same locations.
2. To determine the kinetics of the uptake and secretion of radioiodines in the milk of dairy cows following ingestion of contaminated hay.
3. To measure the relative efficiencies of high and low volume air samplers for collection of radioiodines.
4. To test an air sampling device designed to remove all biologically available radioiodine.
5. To determine soil and vegetation deposition, surface dose rates and other ancillary data as time and the equipment available permit.

II. EXPERIMENTAL DESIGN

Based on Weather Bureau predictions of wind direction, four stations were established downwind from the reactor as shown in Figure 1. Each station included 27 bales of alfalfa hay, stacked 3 x 3 x 3; and loose alfalfa hay piled 18" high on a 160 square feet sheet of plastic. Each station also included film badges, high and low volume air samplers, fallout trays and precipitation collectors.

Fifteen lactating Holstein cows from the U. S. Public Health Service dairy herd were selected for this experiment. Two groups of six cows each were fed the loose hay from the two piles containing the most activity, as measured after the test, and three cows were used as controls. The cows were maintained on a normal twice-a-day milking schedule. The radioiodine content of each milking of each cow was assayed to determine the individual variation in ingestion and milk secretion of iodine in the cow.

Soil and vegetation samples were taken before and immediately after the event and at later times after the event to determine the change of activity with time.

In addition to the high volume and low volume air samplers, an experimental "absolute" iodine sampler was used for this test. This sampler was designed to remove all biologically available iodine from an air sample. The effluent from the sampler was trapped in a reservoir and a group of ten rats was allowed to breathe it. A similar group of rats was directly exposed to the cloud from TNT. Determination of the radioiodine in the pooled thyroids of each group, excised 48 hours after exposure, was used to estimate the efficiency of the sampler.

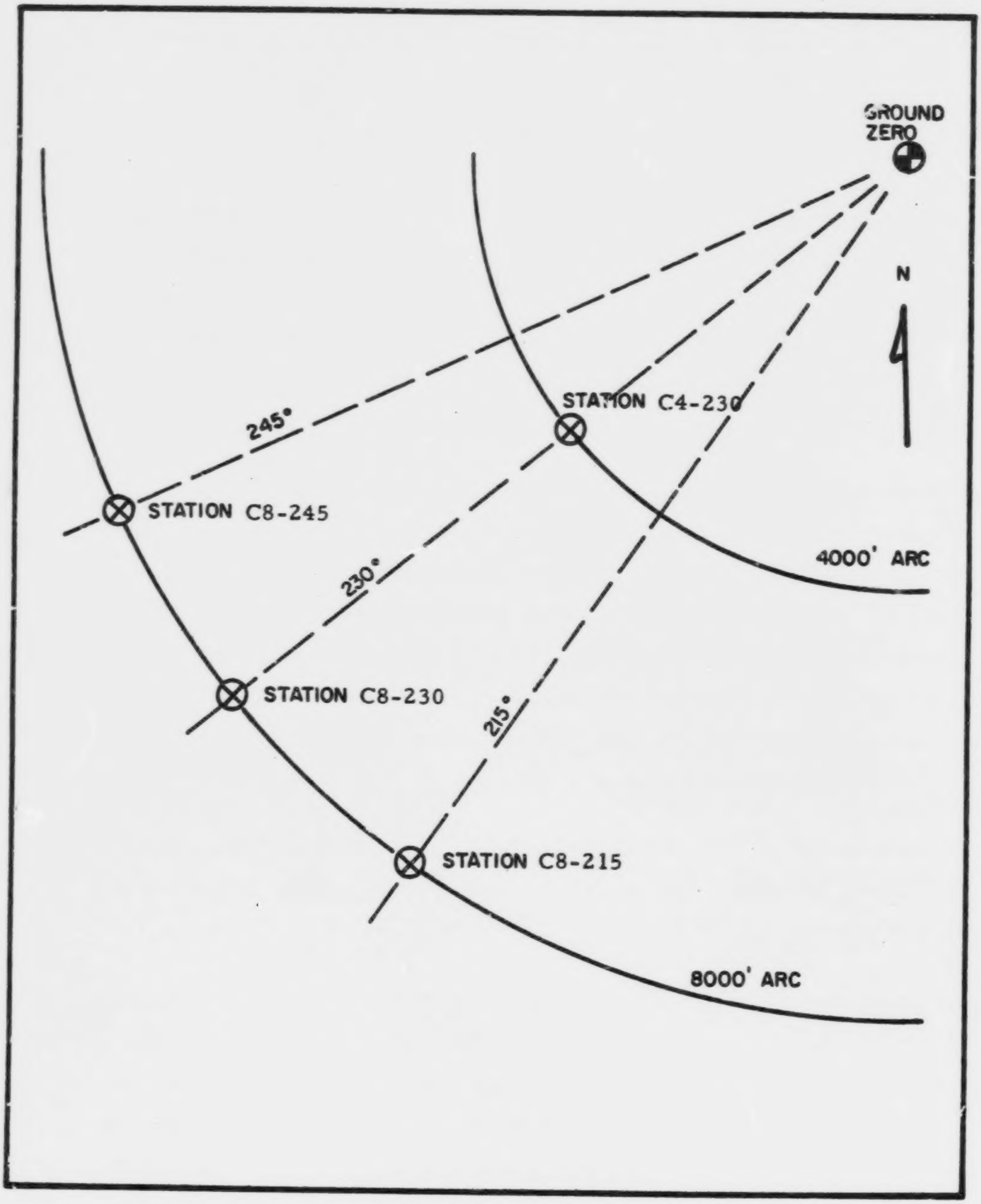
GROUND ZERO
N
STATION C4-230
245°
STATION C8-245
230°
4000' ARC
STATION C8-230
215°
STATION C8-215
8000' ARC

Figure 1. Station locations for TNT.

The stacked hay bales were sampled by taking cores which were used to determine uniformity of surface contamination of the stacks and depth of radioiodine penetration into the bales. No baled hay was fed to the cows. The loose hay piles were sampled in situ and after removal to the dairy barn. One sample was taken daily from each batch of loose contaminated hay fed to each cow to determine both the amounts of radioiodines ingested by the cows and the effective half-lives of the radioiodines on the hay.

Survey meter readings were taken at each station after the test to determine the activity deposited on the stations.

III. HAY STUDY

A. Procedure

At each of the four stations were a stack of baled alfalfa hay and a pile of loose alfalfa hay. The stacks of baled hay were used to determine, for this geometric arrangement, the characteristics of the radioiodine deposition and retention on hay, including the extent of penetration of the radioiodine into the stacks and individual bales. The loose hay was used for the ingestion study and for effective half-life determinations.

Analysis of the hay was by gamma spectrometry. The minimum detectable limit for radioiodines with our instrumentation and methods is estimated to be 100 pCi/kg with a precision of ± 100 pCi/kg, or ±50%, whichever is larger.

1. Loose Hay

Survey meter readings after the test indicated that the highest amounts of activity were deposited on Stations C4-230 and C8-215 (Figure 1). The loose hay from these stations was used for the ingestion study. Samples were taken from each pile and placed in plastic bags to be weighed and gamma scanned. The remainder of the hay was taken to the dairy barn to be fed to the study cows. Upon arrival at the barn, an additional sample from the hay which was at Station C8-215 was removed, bagged, and gamma scanned to determine whether handling affected radionuclide content.

Six grab samples were collected each day from each of the two contaminated hay piles (see Section IV). The analytical data from these samples are used to estimate the effective half-life of radioiodines on the hay.

To determine how firmly the radioiodines were bound to the hay, a large sample of loose hay was collected from the contaminated pile, divided into smaller samples and treated as follows:

a. A sample was weighed, gamma scanned and spread loosely in a cage. A fan was arranged to blow room air over the hay at an average speed of 10 mph for one hour. The sample was then reweighed and gamma scanned. The procedure was repeated allowing the air to blow over the same hay for a second hour. This experiment was performed at three and four days after contamination.

b. A sample was weighed, gamma scanned and placed in a one-gallon glass jar. The jar was filled with tap water, capped and shaken thoroughly. The water was drained off, the washing repeated twice more, and then the hay was gamma scanned. This experiment was performed at three, four and five days after the test.

c. A sample was weighed and gamma scanned. Then the leaves and stems were separated as much as possible and each portion counted separately.

To determine any possible migration of radioiodines into hay, several small stems of contaminated hay were split lengthwise and placed on x-ray film. After 48 hours exposure, the split stems were removed and the film was developed.

2. Baled Hay

To estimate the penetration of radioiodines into hay bales, core samples were taken from top and front-facing bales (Figure 2)

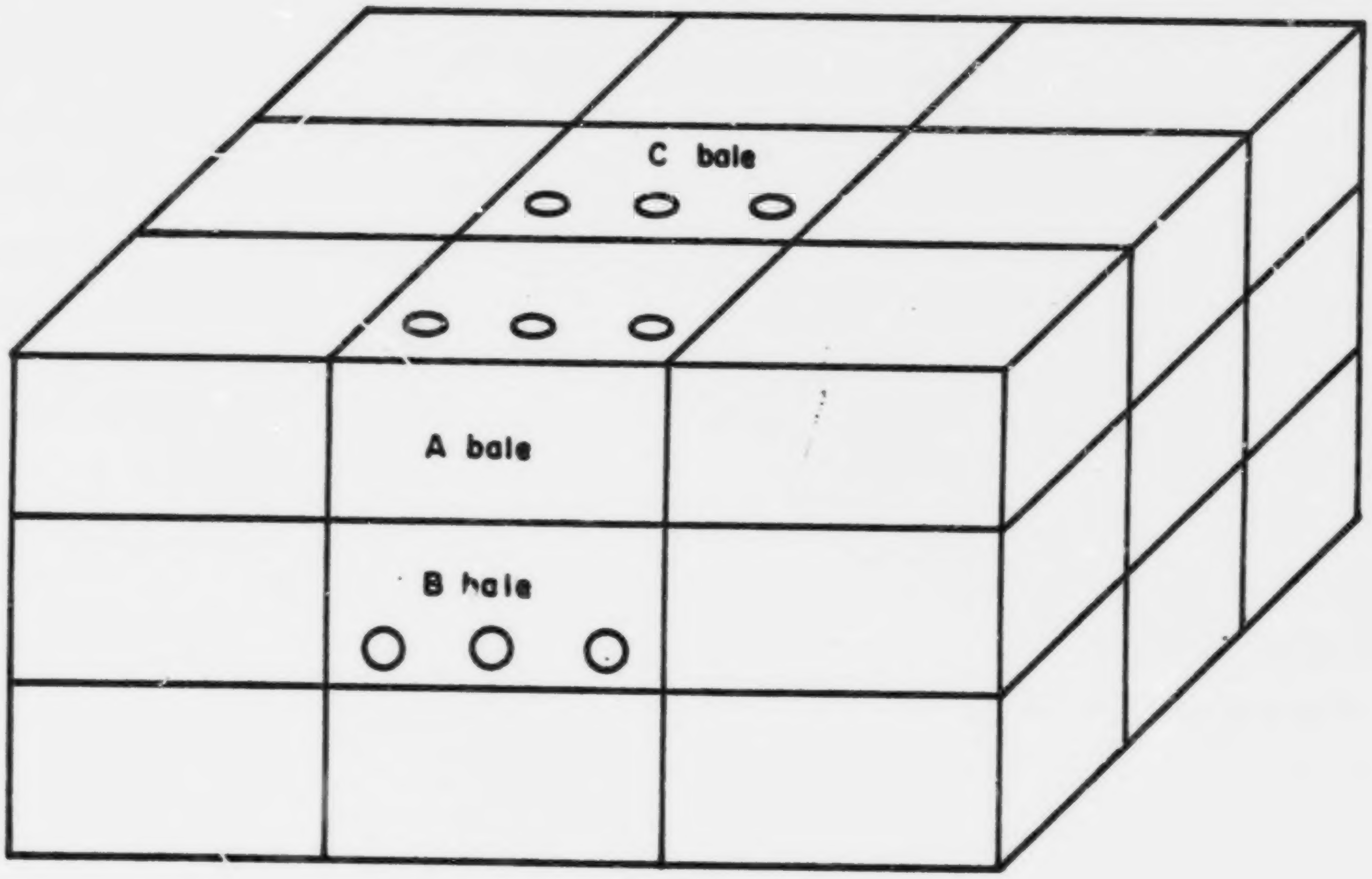
C bale
A bale
B bale

Figure 2. Baled hay stacking diagram. Front of diagram is facing Test Cell C. Location of core samples is indicated by circles on bales sampled.

from the stacked hay at Stations C4-230 and C8-215. The corer was a piece of steel pipe four inches in diameter. One end of the pipe was sharpened and filed in a sawtooth pattern. A bale was cored by placing the most radioactive side down on a piece of masonite. Starting from the opposite side the corer was rotated until it penetrated the bale. The corer was then placed in a plastic bag and the core expelled by holding it in place while the corer was withdrawn. The core was then wrapped with the plastic bag and bound tightly to form a cylinder four inches in diameter and fourteen to sixteen inches long. Three cores were taken from each bale and each core was then sawed into three inch segments. The first three inches of each of the three cores were combined to form one sample, the second three inches combined to form another sample, and so on.

Core samples were taken five hours after exposure to the radioactive cloud. The stack at C4-230 was sampled from bales A, B and C as shown in Figure 2. The stack at C8-215 was sampled from bales B and C while the stacks at C8-230 and C8-245 were sampled from bale B only.

In addition to the hay placed at fixed stations, eleven bales of hay were placed in a truck for use as a mobile station. When the effluent cloud direction was determined, the truck was driven into the path of the cloud at about 16 miles from the reactor, and the bales removed and stacked on the ground in a 3 x 2 x 2 configuration. Core samples from this stack were taken from both vertical and horizontal surfaces.

B. Results

1. Loose Hay

The results of sample analyses in the effective half-life study are shown in Figure 3 and Table 1. The "least squares" lines as fitted to these data indicate ^{131}I effective half-lives of 2.4 days and 4.0 days at Stations C8-215 and C4-230 respectively. For the calculation of the effective half-life at C8-215 one point has been rejected as an outlier. Also non detectable values were rejected.

Table 1. Data for effective half-life of radioiodines in loose hay.

	pCi/kg			
Date	^{131}I	^{132}I	^{133}I	^{135}I
		Station C4-230		
1/12/65*	-	3,100	2,700	64,000
1/13/65	1,590	4,100	10,670	2,300
1/14/65	960	12,000	2,910	-
1/15/65	-	-	-	-
1/16/65	-	-	-	-
1/17/65	-	-	-	-
1/18/65	610	400	-	-
		Station C8-215		
1/12/65*	-	4,800,000	160,000	33,000*
1/12/65**	-	11,000	2,300	-**
1/13/65	1,060	20,000	6,240	4,800
1/14/65	5,120	20,000	3,520	-
1/15/65	-	-	-	-
1/16/65	2,120	3,500	1,760	-
1/17/65	2,250	3,900	2,730	-
1/18/65	1,530	2,100	1,990	-

*in situ

**After move and prior to feeding (all other hay samples were taken from cow mangers). A dash (-) indicates non-detectable.

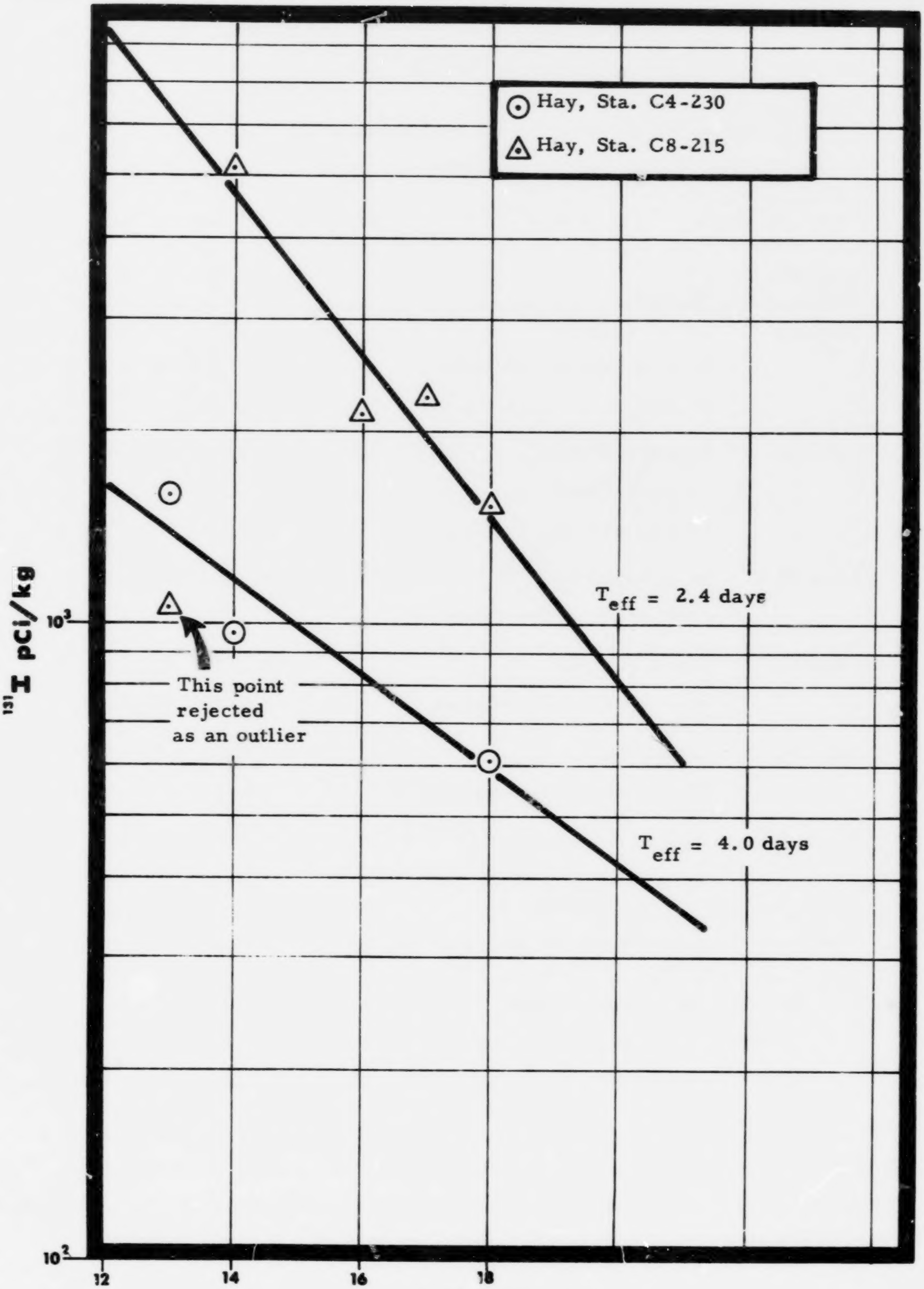

Figure 3. Effective half lives of ^{131}I in loose hay.

The results of the experiments to determine the firmness of binding of radioiodines to the hay are shown in Table 2.

Table 2. Removal of radioiodines from loose hay at station C8-215.

Date	Procedure	pCi/kg ^{131}I	pCi/kg ^{133}I
1/15/65	Initial Activity	30,000	34,000
	10 mph wind for one hour	22,000	26,000
	10 mph wind for two hours	10,000	16,000
1/16/65	Initial Activity	14,000	18,000
	10 mph wind for one hour	14,000	16,000
	10 mph wind for two hours	12,000	13,000
1/15/65	Initial Activity	23,000	32,000
	After three water washes	600	1,000
1/16/65	Initial Activity	22,000	28,000
	After three water washes	10,000	16,000
1/17/65	Initial Activity	20,000	25,000
	After three water washes	7,000	13,000
1/15/65	Whole hay samples	42,000	50,000
	Leaves only	39,000	45,000
	Stems only	3,000	5,000

The autoradiographs showed no evidence of migration of radioactivity into the hay stems. If a very small amount did migrate, a longer exposure time would have been necessary to demonstrate this.

2. Baled Hay

The results of the core analyses are shown in Table 3. None of the cores from the bales from the mobile station showed detectable activity.

Table 3. Results of analyses of cores from stacked, baled hay.

Location of Stack	Bale No.	Depth in Bale*	pCi/kg			
			^{131}I	^{132}I	^{133}I	^{135}I
C8-215	B	(None detectable in any section)				
C8-215	C	1st 3"	-	2,300	2,200	3,300
		other sections	-	-	-	-
C4-230	A	1st 3"	-	1,100	910	9,200
		mid sections	-	-	-	-
		end 3"	-	2,100	6,100	15,000
	B	1st 3"	-	2,300	3,600	23,000
		other sections	-	-	-	-
	C	1st 3"	-	380	940	9,200
		other sections	-	-	-	-
C8-230	B	(None detectable in any section)				
C8-245	B	(None detectable in any section)				

*Each sample represents combined 3" sections from the three cores in each bale.
A dash (-) indicates non-detectable.

C. Discussion

At Station C8-215 there was apparently no penetration of radioiodine between bales and no detectable activity on the vertical hay surface facing Test Cell C. The results of the core analyses indicate that no detectable amounts of radioiodine penetrated beyond three inches into the single bales of hay.

The measurements on bale A at C4-230 show that there was penetration of radioiodines between bales A and B. Also, the data from C4-230 clearly indicate that a greater amount of radioiodine was retained by the vertical hay surface facing Test Cell C than by the horizontal hay surface.

The study of radioiodine binding to the hay at C8-215 indicates that much of the material is loosely bound, since it is easily removed by either blowing it off or by washing in tap water. A portion of the radioiodines is more firmly bound to the hay and there is some indication that this fraction increases with time after contamination. It was not possible, in these simple experiments, to determine whether the gaseous or the particulate material was the more tightly bound fraction of the deposit.

Separating the leaves from the stems and measuring them separately indicated that most of the deposited activity was with the leaves. It was not possible to determine whether this difference was due entirely to the larger surface area of the leaves, compared to the stems, or whether the different morphology of the two surfaces played any role.

The observed effective half-life on the hay (T_{eff}) requires some comment. The T_{eff} of ^{131}I on pasture has been observed to be about five days.[3,4,5] This is shorter than the physical half-life because of growth of the forage, loss by weathering, loss by diffusion back into the atmosphere, and possibly other factors. All of these factors would apply in the case of hay except that no growth occurs, so one might expect a somewhat longer effective half-life for ^{131}I on hay.

In view of the order of magnitude reduction in radioiodine levels in hay seen after the movement of the hay from its initial location to its storage location, it was assumed that hay at different depths within the loosely piled hay was contaminated to different degrees. The hay sampled in situ was taken from the surface of the pile. The process of picking up the hay with pitchforks and loading it into a wagon certainly mixed some of the less contaminated hay from the bottom of the pile with more contaminated hay from the surface. Thus, the actual pile of hay which was fed each experimental group of cows was far from being contaminated homogeneously. This fact posed real problems in obtaining representative samples of the contaminated hay from each feeding.

All these possibilities cast considerable doubt on any procedure for calculating T_{eff} on hay. Actually, the values which were excluded as being outliers or "non-representative" could have been representative of the actual contamination fed the cows that day, if a greater proportion of less contaminated hay was mixed in with the more contaminated hay than was the case on subsequent days. All of the uncertainties and unexplained variabilities in the ^{131}I on hay data preclude placing confidence on the calculated effective half-lives.

In order to compare the ingested activity to the recovered activity, a smoothing technique consisting of averaging the individual hay sample activities on each day was used (Tables 6 and 7). This assumes that the activity actually consumed was more uniform than was measured. A comparison of the activity level (pCi/kg) in the hay fed on one day and the activity level (pCi/l) in the milk on the following day for each cow indicates that most of our reported "nondetectable" levels in the hay are too low in comparison to subsequent milk levels. This supports the assumption used in taking the mean value as an approximation to the actual activity in the hay. All values were used in computing the average due to the possibility that a nondetectable level was correct. The averaging method was used in place of other techniques since it is simple and any introduced error is considered to be less than or equal to possible errors associated with other methods.

IV. MILK STUDY

A. Procedure

Fifteen cows, all Holsteins, were selected from the dairy herd for this experiment. Three were used as controls and the remaining twelve were divided into two groups for ingestion of the contaminated hay. Blood samples were taken for protein bound iodine (PBI) determinations by the "Hycel" method. The groups and their average milk production over a thirty day period just prior to this study are shown in Table 4.

Table 4. Experimental cow grouping.

Group I C8-215 Hay			Group II C4-230 Hay			Group III Control Cows		
Cow No.	Avg. Milk liters/day	PBI µg%	Cow No.	Avg. Milk liters/day	PBI µg%	Cow No.	Avg. Milk liters/day	PBI µg%
1*	13.6	4.0	8	14.0	4.9	2	19.6	5.2
11	19.5	5.4	24	18.0	5.0	16	18.2	5.3
13	15.9	5.0	25	14.3	4.3	22	17.5	4.5
21	19.7	4.0	26	26.8	3.8			
23	19.0	3.3	27	18.2	5.0			
29	15.6	4.3	28**	9.4	4.4			

*Milk data eliminated due to development of mastitis during experiment.
**Milk data eliminated due to drying up during experiment.

After the test, the loose hay at each station was monitored with survey instruments, and the pile at station C8-215 was marked for feeding to Group I cows while Group II cows received the hay from station C4-230. Each cow was fed 10 kg. of hay each day until the supply of contaminated hay was exhausted. The hay was weighed for each cow, put into individual mangers, and a grab sample of approximately 150 g taken.

The hay was fed immediately after the morning milking and any hay remaining was removed and weighed just prior to the evening milking to determine the actual amount consumed by each cow. Water and grain samples were also taken daily to measure any possible radioiodine contribution from these sources.

The cows were milked by the use of individual Surge Bucket milkers. At the morning milking, one gallon and one liter samples were taken from each cow; one gallon samples were also taken at the afternoon milking. This sampling schedule was maintained until radioiodine activity was no longer detectable. Formaldehyde was added to each gallon sample but the milk was neither pasteurized nor homogenized.

The one-liter morning sample, without added formaldehyde, was passed through a resin column to separate iodine. The method used was that described by Kahn[6] in which a final AgI precipitate is beta-counted. This procedure was used with hopes of detecting lower levels of activity than is possible by gamma spectrum analysis.

The one gallon morning and afternoon samples from each cow were submitted for gamma spectrometry and subsequent chemical analysis. The isotopes measured and the precisions are set forth in Table 5. For radioiodine output in milk calculations, an activity listed as non-detectable is assumed to represent a concentration of 10 pCi/liter (one-half of the 20 pCi minimum detectable level) for at least two milkings following the last milking with a detectable amount of activity. Blood samples were taken from each cow toward the end of the experiment for a final PBI determination.

Table 5. **Analytical precision for milk samples.**

Element	Analytical Method	Units	Minimum Detectable	Precision*
^{131}I	γ-spectrometry	pCi/l	20	±20 or 10%
^{133}I	γ-spectrometry	pCi/l	20	±20 or 10%
^{137}Cs	γ-spectrometry	pCi/l	10	±10 or 20%
K	γ-spectrometry, ^{40}K ratio to total K	gm/l	.01	±10%
^{90}Sr	Radiochemistry	pCi/l	1	± 1 or 5%
Ca	Stable Chemistry	gm/l	.01	± .01

*Use the factor which gives the greater error, e.g., an iodine concentration of 250 pCi/liter requires ±25 pCi/liter for the error (using 10% instead of ±20).

B. Results

The raw data for each of the three groups of cows are presented in the Appendix. In order to plot group averages, the data were rearranged as shown in Tables 6 and 7. The activity of the six grab samples of loose hay was averaged for each day for each group and this average, when multiplied by the amount of hay consumed by each cow, was used to calculate the total intake of each cow and the average intake per cow in each group per day. Similarly, the concentration of radioiodine in the morning milk times the volume of the morning milk plus the concentration in the evening milk multiplied by the volume yields the total daily activity excreted in the milk. This latter value, when divided by the total volume of milk produced that day, gives the average daily pCi/liter. These average milk values are more useful for estimating potential human population doses than are data from individual cows since the great majority of people drink milk from a pool representing one or

Table 6. Radioiodine ingestion and milk content - Group I cows.

Date	Cow No.	kg Hay	pCi/kg Hay		pCi Intake		Total pCi in Milk		Liters Milk	Avg. pCi/liter	
			^{131}I	^{133}I	^{131}I	^{133}I	^{131}I	^{133}I		^{131}I	^{133}I
1/13	1		50**	50**							
	11	10.0	50	6,000	10,600	62,400					
	13	5.9	50	9,600	6,200	36,800					
	21	7.7	6,100	6,000	8,200	48,000					
	23	9.5	50	5,800	10,100	59,300					
	29	9.5	50	10,000	10,100	59,300					
Average			1,060	6,240	9,040	53,160					
1/14	1		8,700	1,000							
	11	7.7	7,000	5,000	39,400	27,100	1,210	8,010	14.6	83	550
	13	8.9	3,900	50	45,600	31,300	640	1,690	12.0	53	140
	21	8.2	50	50	42,000	28,900	780	3,540	11.0	70	320
	23	9.5	50	15,000	48,600	33,400	930	6,290	15.9	58	390
	29	7.3	11,000	50	37,400	25,700	440	3,500	11.1	40	320
Average			5,120	3,520	42,600	29,280	800±290*	4,610±2,460	12.9±2.2	61±16	340±140
1/15	1		50	50							
	11	8.6	50	50	430	430	2,160	4,360	18.4	120	240
	13	9.3	50	50	460	460	880	1,420	14.6	60	97
	21	8.6	50	50	430	430	1,820	2,440	16.4	110	150
	23	8.6	50	50	430	430	1,530	2,240	20.4	75	110
	29	8.6	50	50	430	430	440	860	11.1	40	78
Average			50	50	440	440	1,370±690	2,260±1,310	16.2±3.5	81±33	135±63

* ± one standard deviation.

**Non detectable; one-half the detectable value used for averaging purposes.

Table 6. Radioiodine ingestion and milk content - Group I cows. (Continued)

Date	Cow No.	kg Hay	pCi/kg Hay		pCi Intake		Total pCi in Milk		Liters Milk	Avg. pCi/liter	
			^{131}I	^{133}I	^{131}I	^{133}I	^{131}I	^{133}I		^{131}I	^{133}I
1/16	1		1,600	50							
	11	8.2	2,900	50	17,400	14,400	2,110	1,650	21.3	99	78
	13	7.7	2,600	2,800	16,300	13,600	720	360	15.3	47	24
	21	7.7	50	50	16,300	13,600	1,690	1,560	15.9	110	98
	23	9.5	2,600	3,000	20,100	16,700	1,210	1,160	17.3	70	67
	29	5.4	3,000	4,600	11,400	9,500	510	440	12.6	40	35
Average			2,120	1,760	16,300	13,560	1,250±650	1,030±600	16.5±3.1	73±30	60±30
1/17	1		50	50							
	11	9.5	1,200	3,000	21,400	25,900	1,590	610	18.2	87	34
	13	6.4	50	2,800	14,400	17,500	640	320	14.6	44	22
	21	8.2	2,200	50	18,400	22,400	1,200	460	15.5	77	30
	23	9.5	2,100	3,800	21,400	25,900	1,350	300	17.3	78	17
	29	9.5	7,900	6,700	21,400	25,900	740	170	11.3	65	15
Average			2,250	2,730	19,400	23,520	1,100±400	370±160	15.4±2.6	70±16	24±8
1/18	1		1,800	8,500							
	11	9.5	1,400	50	14,500	18,900	1,590	200	19.9	80	10
	13	9.1	1,100	2,200	13,900	18,100	600	97	15.1	40	6
	21	10.0	50	50	15,300	19,900	990	160	15.5	64	10
	23	10.0	50	50	15,300	19,900	640	120	12.0	53	10
	29	9.5	4,800	1,100	14,500	18,900	440	66	11.5	38	6
Average			1,530	1,990	14,700	19,140	850±450	130±52	14.8±3.3	55±17	8±2
1/19	11						780		17.3	45	
	13						590		13.3	45	
	21						900		15.9	56	
	23						740		16.4	45	
	29						620		9.7	63	
Average							730±120		14.5±3.0	51±8	

Table 6. Radioiodine ingestion and milk content - Group I cows. (Continued)

Date	Cow		pCi/kg Hay		pCi Intake		Total pCi in Milk		Liters	Avg. pCi/liter	
	No.	kg Hay	^{131}I	^{133}I	^{131}I	^{133}I	^{131}I	^{133}I	Milk	^{131}I	^{133}I
1/20	11						600		22.1	27	
	13						410		15.5	26	
	21						580		15.9	37	
	23						870		18.6	47	
	29						620		15.5	40	
Average							620±160		17.5±2.8	35±9	
1/21	11						320		19.0	17	
	13						780		14.2	27	
	21						370		12.4	30	
	23						300		17.3	17	
	29						250		12.4	20	
Average							400±210		15.1±2.9	22±6	
1/22	11						460		19.9	23	
	13						200		15.5	13	
	21						280		16.8	17	
	23						220		16.4	13	
	29						190		15.1	13	
Average							270±110		16.7±1.8	16±4	
1/23	11						120		19.0	7	
	13						140		14.2	10	
	21						160		15.9	10	
	23						170		16.8	10	
	29						190		12.4	15	
Average							160±26		15.7±2.5	10±3	

Table 7. Radioiodine ingestion and milk content - Group II cows.

Date	Cow No.	kg. Hay	pCi/kg Hay		pCi Intake		Total pCi in Milk		Liters Milk	Avg. pCi/liter	
			^{131}I	^{133}I	^{131}I	^{133}I	^{131}I	^{133}I		^{131}I	^{133}I
1/13	8	10.0	50**	12,000	15,900	106,700					
	24	10.0	50	11,000	15,900	106,700					
	25	10.0	2,100	12,000	15,900	106,700					
	26	10.0	5,000	9,200	15,900	106,700					
	27	10.0	2,300	12,000	15,900	106,700					
	28		50	7,800							
Average			1,590	10,670	15,900	106,700					
1/14	8	8.2	50	50**	7,900	23,900	600	3,920	11.1	54	350
	24	9.5	50	50	9,100	27,600	710	4,210	13.2	54	320
	25	9.5	50	50	9,100	27,600	500	3,490	9.3	54	380
	26	9.1	1,900	6,100	8,700	26,500	1,590	10,070	24.6	65	410
	27	9.5	2,000	5,200	9,100	27,600	1,030	8,440	14.0	74	600
	28		1,700	6,000							
Average			960	2,910	8,780	26,640	890±430*	6,030±2,950	14.4±5.8	60±9	410±110
1/15	8	9.1	50	50	460	460	650	1,670	8.9	73	190
	24	9.5	50	50	480	480	1,190	2,270	15.5	77	150
	25	9.5	50	50	480	480	750	1,460	10.6	71	140
	26	10.0	50	50	500	500	1,990	4,330	26.8	74	160
	27	10.0	50	50	500	500	2,060	4,450	19.9	100	220
	28		50	50							
Average			50	50	480	480	1,330±650	2,840±1,420	16.3±7.1	79±12	170±32

* ± one standard deviation.

** Non detectable; one-half the detectable value used for averaging purposes.

Table 7. Radioiodine ingestion and milk content - Group II cows. (Continued)

Date	Cow No.	kg. Hay	pCi/kg Hay		pCi Intake		Total pCi in Milk		Liters Milk	Avg. pCi/liter	
			^{131}I	^{133}I	^{131}I	^{133}I	^{131}I	^{133}I		^{131}I	^{133}I
1/16	8	7.3	50	50	360	360	510	840	13.7	37	61
	24	8.2	50	50	410	410	1,160	800	18.2	64	44
	25	9.1	50	50	460	460	740	690	11.5	64	60
	26	7.7	50	50	380	380	2,050	1,750	24.4	84	72
	27	9.1	50	50	460	460	1,690	1,620	19.5	87	83
	28		50	50							
Average			50	50	410	410	1,230±630	1,140±490	17.5±5.0	67±20	64±14
1/17	8	5.9	50		300		370	170	10.2	36	16
	24	8.2	50		410		650	84	16.4	40	5
	25	8.2	50		410		500	120	12.0	42	10
	26	8.6	50		430		1,230	720	27.5	45	26
	27	8.2	50		410		930	170	17.3	54	10
	28		50								
Average			50		390		740±340	250±260	16.6±6.6	43±7	13±8
1/18	8	9.1	50		460		410	84	13.7	30	6
	24	9.1	50		460		690		17.7	39	
	25	9.5	50		480		280		12.0	24	
	26	9.5	3,400		480		810	280	28.4	28	10
	27	9.5	50		480		720		19.0	38	
	28		50								
Average			610		470		580±220	73±120	18.2±6.3	32±6	3±5

Table 7. Radioiodine ingestion and milk content - Group II cows. (Continued)

Date	Cow		pCi/kg Hay		pCi Intake		Total pCi in Milk		Liters	Avg. pCi/liter	
	No.	kg. Hay	^{131}I	^{133}I	^{131}I	^{133}I	^{131}I	^{133}I	Milk	^{131}I	^{133}I
1/19	8						380		11.5	33	
	24						370		14.6	25	
	25						320		8.9	36	
	26						760		25.2	30	
	27						750		15.1	50	
Average							520±210		15.1±6.1	35±9	
1/20	8						280		14.2	20	
	24						350		16.8	21	
	25						130		13.3	10	
	26						350		24.4	14	
	27						530		18.2	29	
Average							330±140		17.4±4.3	19±7	
1/21	8						150		14.6	10	
	24						180		18.2	10	
	25						180		11.1	16	
	26						400		24.8	16	
	27						170		14.2	12	
Average							220±100		16.6±5.1	13±3	
1/22	8								13.7		
	24								19.0		
	25						62		8.4	7	
	26						390		28.8	14	
	27						190		18.6	10	
Average							130±160		17.7±7.4	6±6	

more dairy herds. The individual cow data yield ranges of values measured and such data are necessary to estimate possible maximum individual human doses. Average ^{131}I excretion in milk data are plotted in Figures 4 and 5. The plots for the individual cows are included in the Appendix. Cow No. 1 in Group I and Cow No. 28 in Group II were eliminated since No. 1 developed mastitis and No. 28 was drying up during the course of the experiment; thus, the data plotted in Figures 4 and 5 are the average values for five cows in each group. The same applies to Figure 6 which is the graph of average ^{133}I excretion in milk for the two groups.

Data on the average K, Ca, ^{90}Sr and ^{137}Cs concentrations and the average liters of milk per day for the two groups are shown in Figures 7 and 8. The K, Ca and milk production data suggest that little, if any, change occurred in the milk metabolism of the cows during the course of this experiment. The PBI values dropped to 85% of the pretest values, but this occurred in the control cows also and was probably a seasonal effect.

The one-liter milk samples collected each morning were analyzed for radioiodine by passing the milk through ion exchange resin, eluting the iodine, precipitating as AgI, and beta counting the precipitate in a low-background beta counter. During the time ^{133}I was present in the samples, the beta results were corrected by using the 131/133 ratio computed from the gamma spectrometry of the one-gallon milk samples collected simultaneously.

The ^{131}I results by the ion exchange method for both groups of cows are shown in Figure 9 as percent of the value determined by gamma spectrometry. The individual percentage of the 58 comparison samples as well as the average percentage is plotted against activity level as determined by gamma scan.

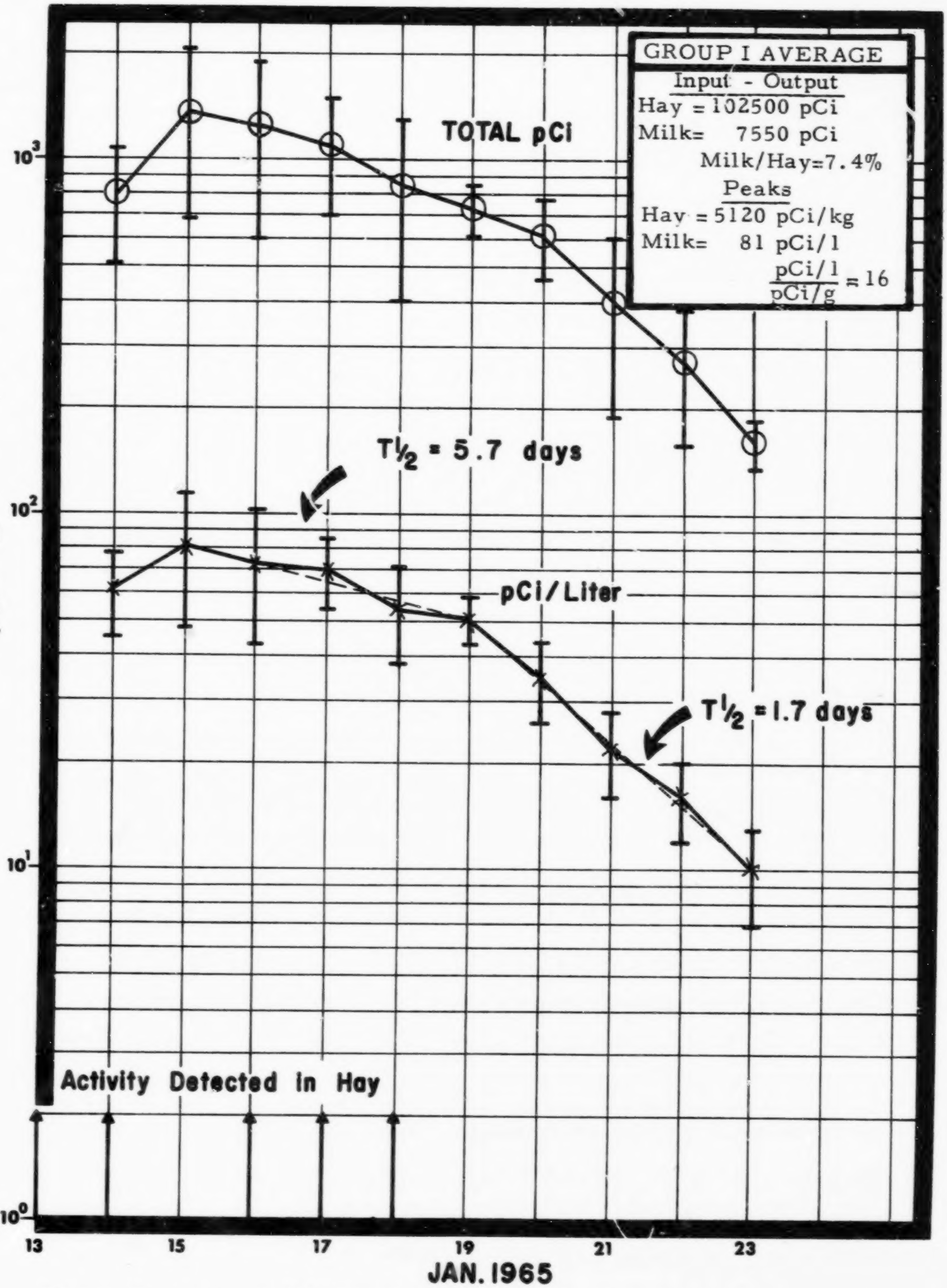

Figure 4. Average ^{131}I excretion in milk for Group I cows.

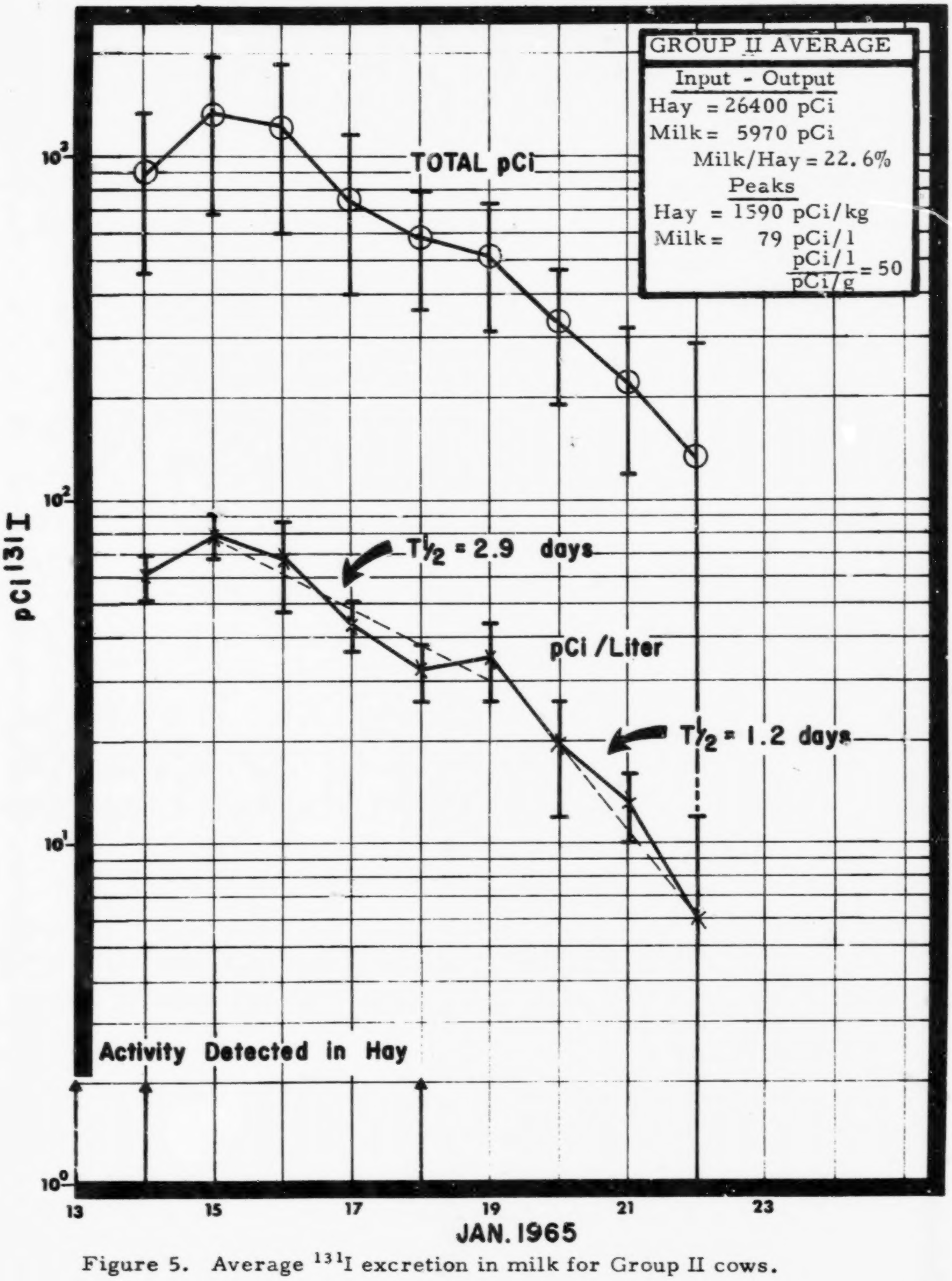

Figure 5. Average ^{131}I excretion in milk for Group II cows.

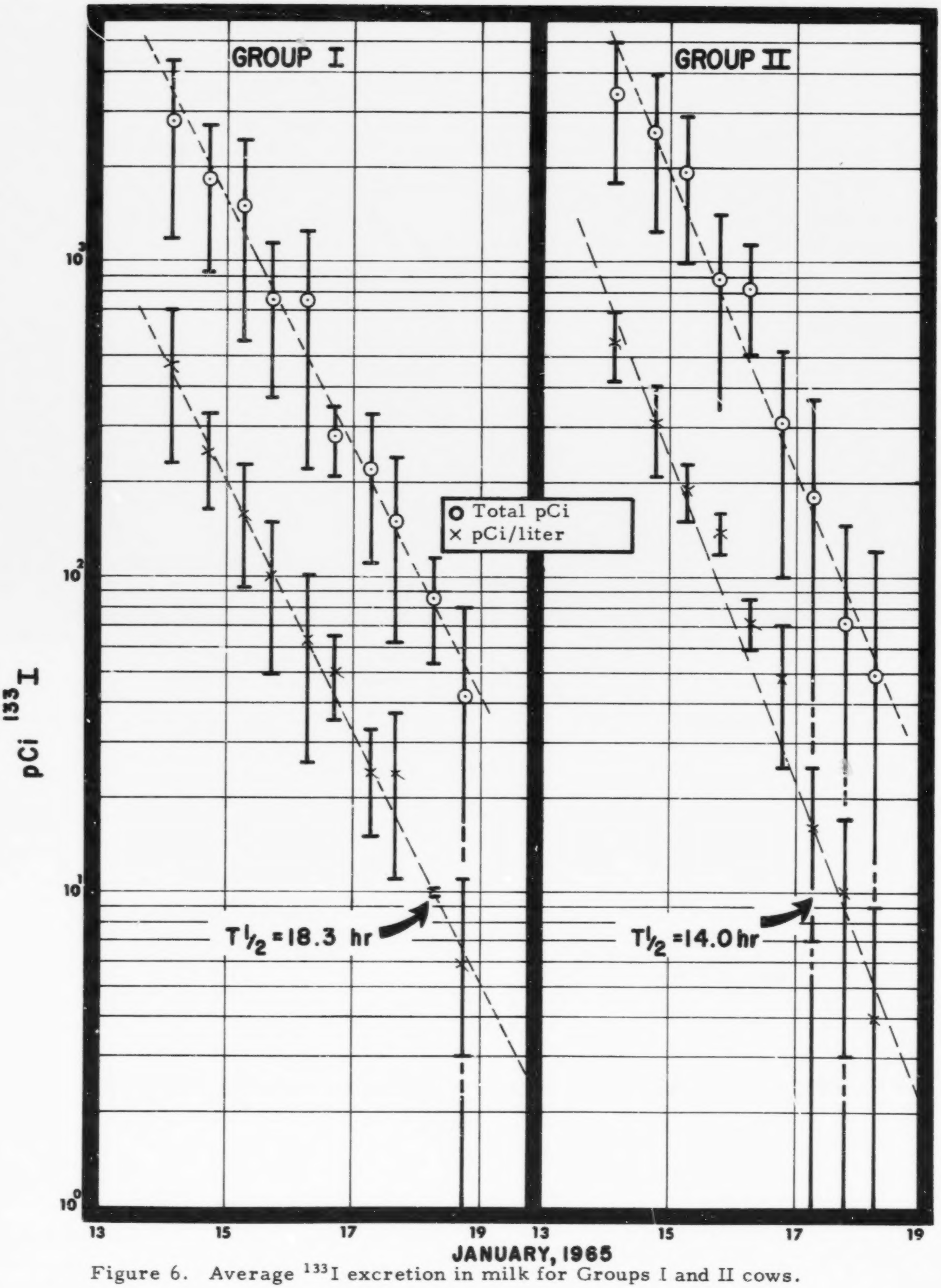

Figure 6. Average ^{133}I excretion in milk for Groups I and II cows.

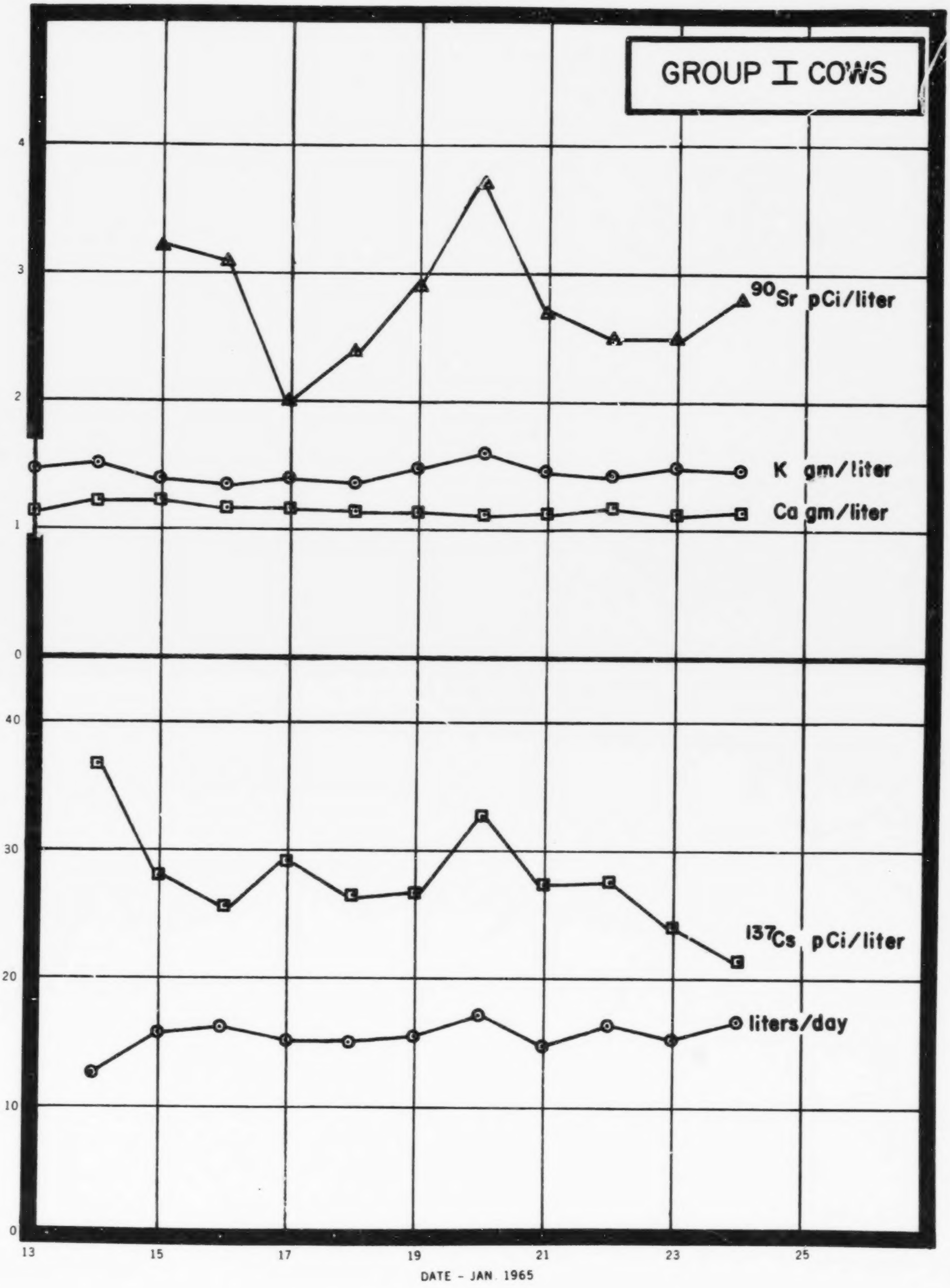

Figure 7. Average K, Ca, ^{90}Sr, ^{137}Cs and milk production for Group I cows.

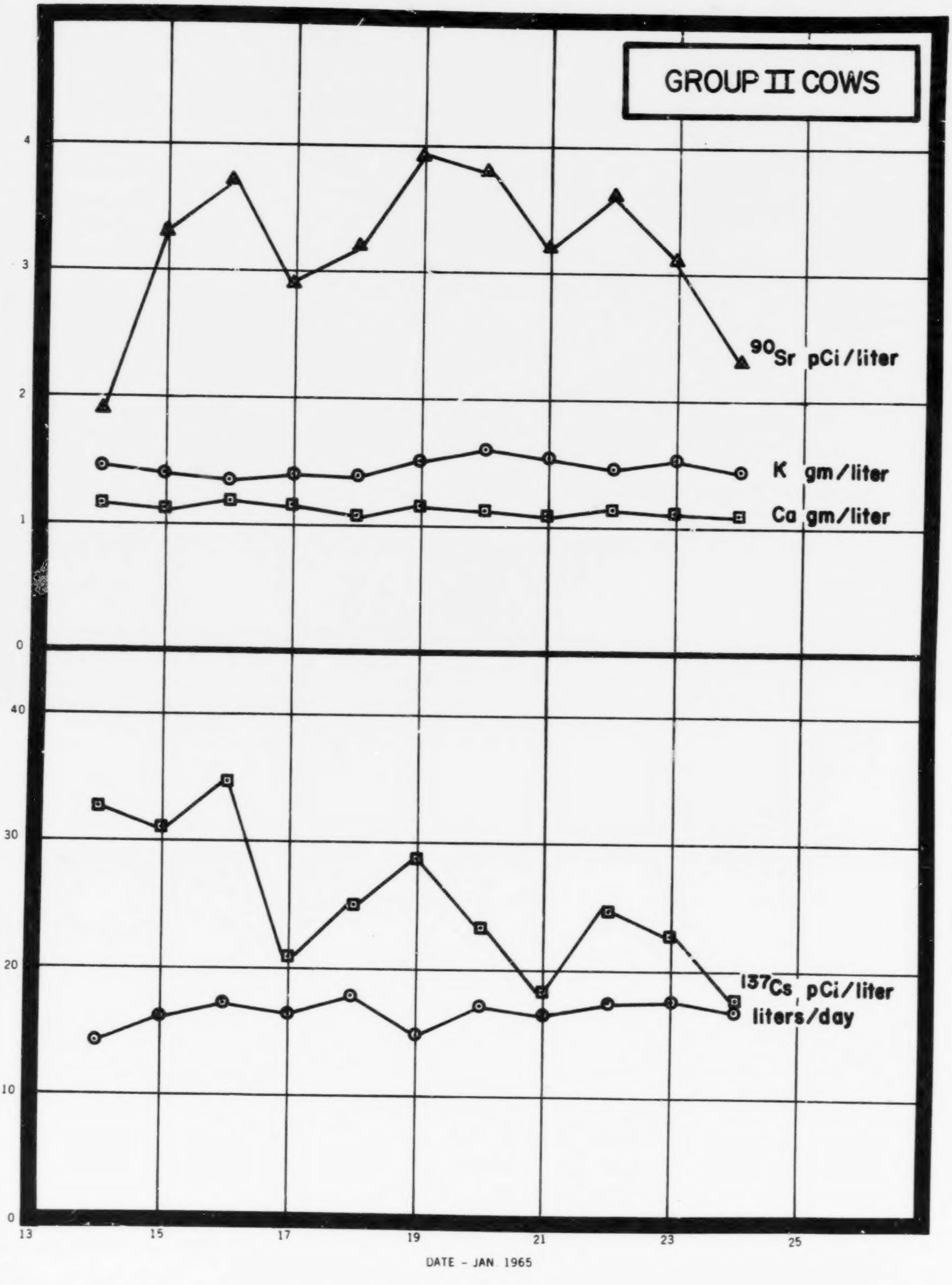

Figure 8. Average K, Ca, ^{90}Sr, ^{137} Cs and milk production for Group II cows.

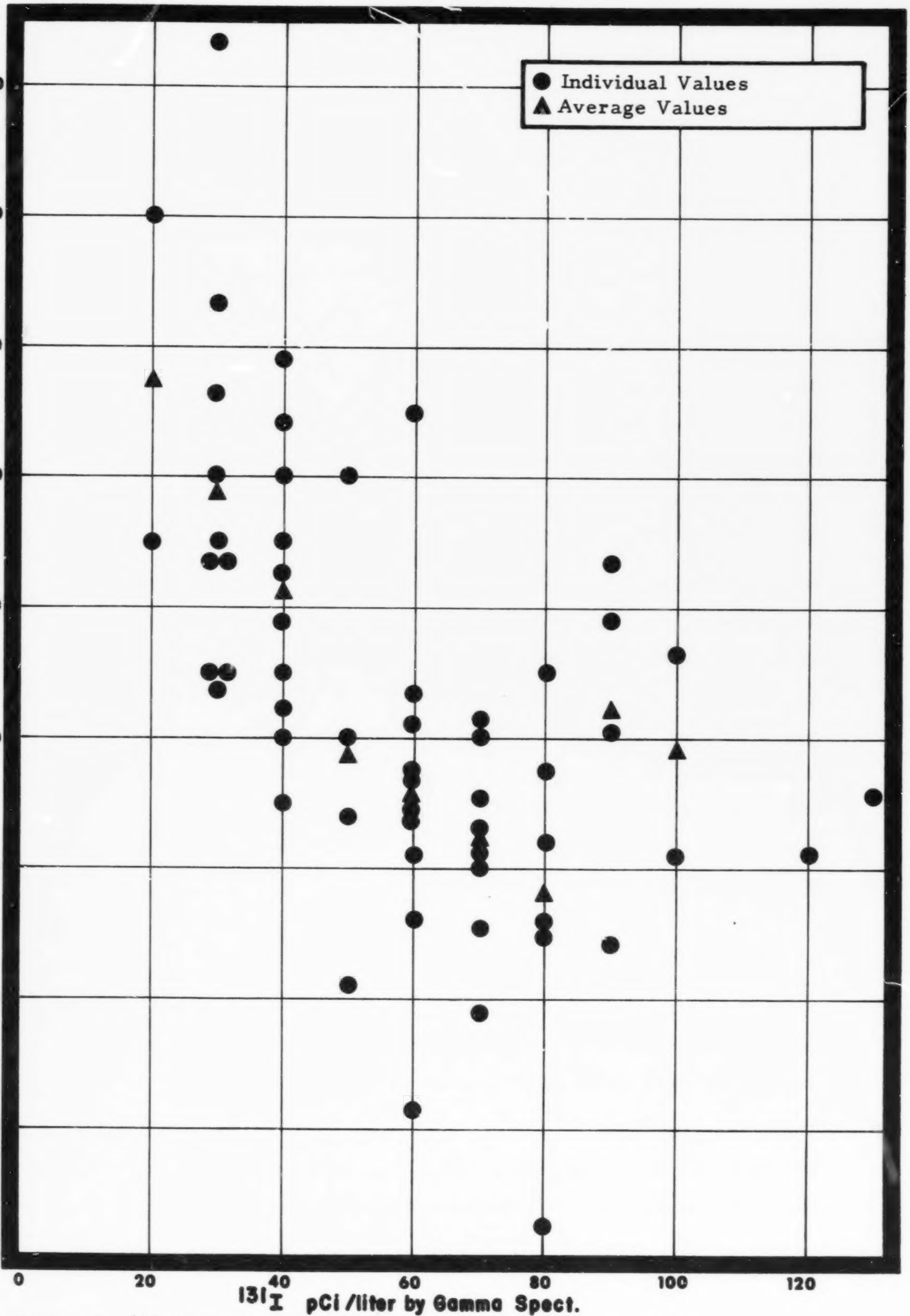

Figure 9. ^{131}I in milk; ion exchange - gamma scan comparison

Table 8 presents, for the first six milkings following the ingestion of contaminated hay, the maximum and minimum values of ^{133}I measured in the milk of different cows within each group together with the milk production and PBI values (Table 4) for the cows exhibiting the extremes. The largest ratio between the maximum and minimum values occurred at the a.m. milking on January 14 in Group I and was 4.6. The average maximum/minimum ratio for Group I of 3.4 appears to be different from the average ratio for Group II, which was 1.7. The reason for this apparent difference is unknown but a possible explanation might be that the hay fed Group II cows was more uniformly contaminated than was the hay fed Group I cows. This supposition, however, is not borne out by the hay data.

If one compares the amount of milk produced by the cow having the maximum ^{133}I concentration in its milk t[illegible]e amount of milk produced by the cow having the minimum ^{133}I concentration for each milking, an important qualitative finding emerges. In 14 out of 15 cases the cow producing the maximum concentration also produced more milk than the cows producing the minimum concentration. There is no explanation for this finding and there is no apparent quantitative relationship between the concentration of ^{133}I in the milk of a single cow and the milk production of the same cow.

C. Discussion

From the data obtained after feeding contaminated hay to these cows, several ratios can be calculated. A resume of these ratios and other data pertinent to these experiments is shown in Table 9.

The comparisons in Table 9 indicate that the two groups of cows reacted similarly to the ^{133}I exposure, where the total intake was similar, as shown by the percent of the intake appearing in milk and the milk/hay

Table 8. Range of ^{133}I values for individual cows within groups.

Date (Jan. 1965)	Max. (pCi/l)	Cow	Milk Produced (liter)	PBI (μg%)	Min. (pCi/l)	Cow	Milk Produced (liter)	PBI (μg%)	Max/Min
				GROUP I COWS					
14, a.m.	830	11	6.2	5.4	180	13	5.3	5.0	4.6
14, p.m.	340	11	6.3	5.4	110	13	6.6	5.0	3.1
15, a.m.	270	11	10.8	5.4	90	29	4.4	4.3	3.0
15, p.m.	190	11	7.5	5.4	70	13	6.6	5.0	
						29	6.6	4.3	2.7
16, a.m.	110	21	11.0	4.0	20	13	9.7	5.0	*
16, p.m.	70	21	4.8	4.0	30	13	5.5	5.0	*
Average			8.1	4.9			6.4	4.8	3.4
				GROUP II COWS					
14, a.m.	810	27	5.5	5.0	460	8	4.8	4.9	1.8
14, p.m.	470	27	8.3	5.0	200	24	7.7	5.0	2.4
15, a.m.	250	27	13.2	5.0	160	24	10.1	5.0	1.5
						25	5.7	4.3	
15, p.m.	170	27	6.6	5.0	110	25	4.8	4.3	1.5
16, a.m.	90	27	12.7	5.0	60	24	12.3	5.0	1.5
						25	6.6	4.3	
16, p.m.	70	27	6.6	5.0	10	24	5.7	5.0	*
Average			8.8	5.0			7.2	4.7	1.7
Grand Average			8.4	5.0			6.8	4.8	

*This ratio considered to have little reliability for cases where the minimum value in the milk is < 50 pCi/l. Because of this a similar table for ^{131}I is not presented.

Table 9. Average data for comparison of both groups.

	Group I Cows	Group II Cows
Number of Cows	6	6
One Cow Omitted for	Mastitis	Drying up
Cows Compared	5	5
Average Milk l/day	15.5	16.6
Days Fed Activity	6	6
	^{133}I Data	
Total Intake - pCi	695,500	671,200
Total pCi in Milk	42,000	51,700
Percent in Milk	6.0	7.7
Peak in Hay - pCi/kg	6,240	10,670
Peak in Milk - pCi/liter	340	410
Ratio $\frac{\text{pCi/liter}}{\text{pCi/g hay}}$	54	38
Time of Peak - Hour	12	12
T_{eff} During Uptake - Hours	18.3(17.1-19.6)*	14.0(12.6-15.9)
	^{131}I Data	
Total Intake - pCi	512,500	132,200
Total pCi in Milk	37,800	29,800
Percent in Milk	7.4	22.6
Peak in Hay - pCi/kg	5,120	1,590
Peak in Milk - pCi/liter	81	79
Ratio $\frac{\text{pCi/liter}}{\text{pCi/g hay}}$	16	50
T_{eff} During Uptake - Days	5.7(4.0-10.1)	2.9(1.7-9.0)
T_{eff} After Uptake - Days	1.7(1.6-1.9)	1.2(0.9-2.0)

*95% Confidence Interval

ratio. When the total intake was widely different, as in the ^{131}I exposure, the reactions differed. Note that the Group II ^{131}I intake was 1/4, but the percent in milk was three times that of Group I and the milk/hay ratio was three times as great. The differences may be due to the differing intake levels but are more likely due to other factors such as sampling errors, the hay activity measurements, differences in physical characteristics of the contaminant at the different stations, or differences between the two groups of cows which are not apparent in the data analyzed. The T_{eff} of 2.9 days in the milk of Group II cows, which occurred during the feeding period, is shorter than most other times reported in the literature.

Because of the short physical half-life of ^{133}I and its rapidly changing concentration in the milk, it appeared more appropriate to use the average concentration at each milking rather than the average daily concentration. These averages are shown in Table 10 and plotted in Figure 6. From the ^{133}I milk $T_{eff's}$ during feeding for the different groups of cows (Table 9) it is possible to calculate a T_{biol} by use of the standard formula $\frac{1}{T_{eff}} = \frac{1}{T_{biol}} + \frac{1}{T_P}$. These calculations lead to a T_{biol} of 6.3 days for Group I and 1.8 days for Group II. The same calculations for ^{131}I (Table 9) lead to a T_{biol} of 19.8 days for Group I and 4.6 days for Group II. Apparently the contaminant for both ^{131}I and ^{133}I at station C8-215 led to a longer T_{biol} than that at station C4-230.

The analysis by use of the ion exchange-AgI precipitate showed larger amounts of ^{131}I in milk, compared to gamma scan, for activities of 40 pCi/liter or less. At milk levels of 50 pCi/liter or more, the ion exchange method gave results that were less than 80% of the gamma scan results. Such data cast doubt on the usefulness of the method for quantitative analysis. A further trial of this method at higher activity levels is planned for the future at which time the usefulness of the procedure can be more thoroughly evaluated.

Table 10. Iodine-133 results in milk from both groups of cows.

	Group I Milk		Group II Milk	
Date-Time	Total ^{133}I	pCi/l	Total ^{133}I	pCi/l
1/14/65, 0230 (12 hr)*	2,770±1,580**	470±240	3,400±1,620	560±140
1/14/65, 1600 (25.5 hr)	1,820±900	250±85	2,620±1,360	310±99
1/15/65, 0600 (39.5 hr)	1,500±940	160±68	1,950±960	190±39
1/15/65, 1600 (49.5 hr)	760±390	100±50	880±540	140±23
1/16/65, 0600 (63.5 hr)	750±530	64±38	830±320	72±13
1/16/65, 1500 (72.5 hr)	280±71	50±15	310±210	48±23
1/17/65, 0600 (87.5 hr)	220±110	24±9	180±190	16±9
1/17/65, 1500 (96.5 hr)	150±88	24±13	71±76	10±7
1/18/65, 0600 (111.5 hr)	85±32	10±0	49±72	4±5
1/18/65, 1700 (122.5 hr)	42±39	6±5		

*Elapsed time from first feeding.

**± one standard deviation.

V. ENVIRONMENTAL STUDY

A. Procedure

Ancillary studies for this test included fallout trays, high and low volume air samplers, film badges, indigenous vegetation sampling, and soil sampling.

The fallout trays were 4.5 inch diameter stainless steel planchets coated with a non-setting resin to provide a sticky surface for any fallout collected on the tray. The trays were beta counted and analyzed by gamma spectrometry for radioiodines.

Each of the four stations was instrumented with two air samplers. The high volume air sampler used a glass-fiber prefilter followed by an MSA charcoal cartridge and sampled at about 25 cfm. The low volume air sampler used a Millipore type HA prefilter and a cartridge containing charcoal from MSA cartridges and sampled at about 1.4 cfm. The prefilters were beta counted, and the charcoal cartridges were gamma scanned for radioiodines. Two of the prefilters from the high volume samplers were also analyzed for beryllium. The air samplers were turned on just prior to leaving the area before the test and turned off as soon as re-entry was permitted. The prefilters and charcoal cartridges were then changed and 24-hour air samples were taken with the high volume samplers for two days after the test to detect any resuspension of deposited activity. For these later air samples, the filters were both beta counted and gamma scanned.

Soil and vegetation samples were taken near each of the stations on the day of the test, seven days afterward, and eight days afterward (the latter samples were taken after an overnight rain). At each station film badges were placed on stakes located at the corners of a rectangle and placed so they were 14 feet from the corners of the hay stack and 3 feet above ground as shown in Figure 10. They were placed before the test and removed 48 hours later.

Survey meter readings were made at each of the eight stakes at the fixed stations and at the corners and center of each baled hay stack and spread hay pile. The readings were made with an E-500B GM-type survey meter. Readings were made of gamma mR/hr at 3 feet above ground and beta plus gamma at ground level. This was done before the test, and at 3, 24, and 48 hours after the test.

One mobile station was moved into the path of the cloud to assure some contamination of baled hay in case the cloud missed the four fixed stations. This mobile station was equipped with eleven hay bales, portable survey instruments, a fallout tray and high and low volume air samplers. The truck containing this equipment was stationed on a highway approximately 16 miles from Test Cell C so it could be driven into the path of the cloud. Using trajectory information from the control point to select a location, a hay stack was constructed, the fallout tray exposed, air samplers started and soil and vegetation samples taken.

B. Results

The deposition at the fixed stations occurred under slightly unstable weather conditions. During deposition the winds were 16 to 18 mph with about 10° shear to 2,500 feet above ground and there was no inversion at test time.

1. Air Sampling

The results of the air sampling experiment are set forth in Tables 11 and 12. No ^{131}I was detected on either the prefilters or the charcoal

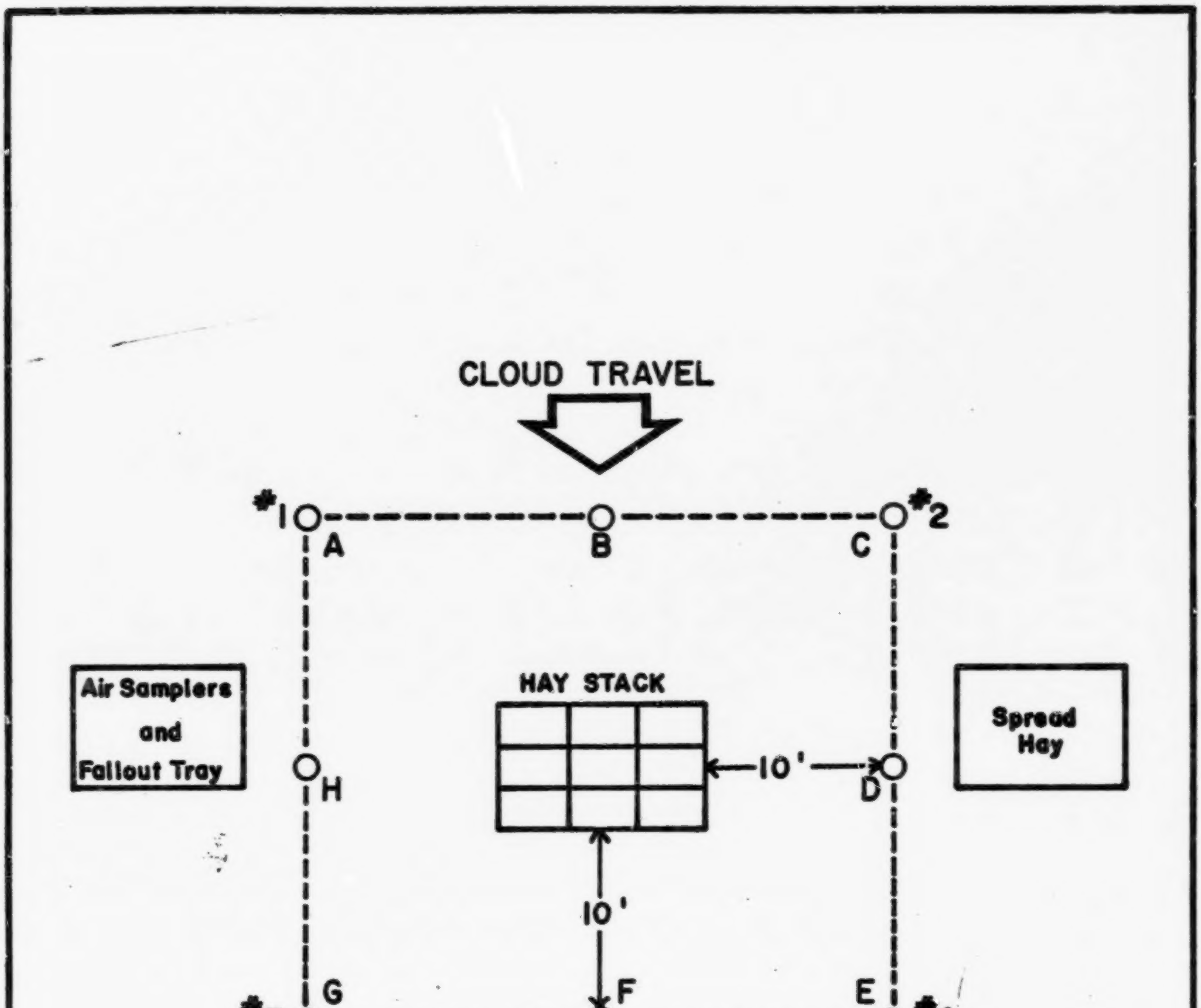
CLOUD TRAVEL
#1
A
B
#2
C
Air Samplers and Fallout Tray
HAY STACK
Spread Hay
H
10'
D
10'
G
F
E
#3
#4

Figure 10. Typical station layout. Film badge at stakes A, C, E and G.

Table 11. Comparison of high volume and low volume air samplers (pCi/m^3).

Date	Location	Sample	Charcoal Cartridge				Filter Gross Beta
			^{131}I	^{132}I	^{133}I	^{135}I	
1/07/65	C8-230	Control HV+LV	---*	---	---	---	---
	C4-230	Control HV+LV	---	---	---	---	---
1/12/65	C4-230	High Volume	---	22	550	4,000	9
		Low Volume	---	75	130	5,200	490
		HV/LV Ratio	---	0.29	4.3	0.76	0.002
	C8-215	High Volume	---	270	900	4,500	6,000
		Low Volume	---	76	130	3,000	6,000
		HV/LV Ratio	---	3.5	7	1.5	1
	C8-230	High Volume	---	11	84	1,700	840
		Low Volume	---	9	---	810	610
		HV/LV Ratio		1.3		2.1	1.4
	C8-245	High Volume	---	2	31	81	47
		Low Volume	---	---	18	---	11
		HV/LV Ratio			1.7		4.1
	Lathrop Wells 16 miles from Test Cell C	High Volume	---	130	300	300	32,000
		Low Volume	---	140	310	1,700	20,000
		HV/LV Ratio		0.93	0.97	0.18	1.6

*A dash (---) indicates non-detectable levels.
HV = High Volume LV = Low Volume

cartridges. Other radioiodines were detected and the data were corrected to reflect their concentration at the end-point of time of collection. The beta counts of the prefilters are also corrected to reflect the concentration at end-point of collection time.

Table 12. High volume air sampler results (pCi/m^3).

Date	Location	Sample	^{131}I	^{132}I	^{133}I	^{135}I	Gross Beta
1/12-1/13	C8-215	Filter	---*	3	14	---	6
		Charcoal	---	2	200	460	
	C8-230	Filter	---	2	47	0	0.06
		Charcoal	---	1	48	140	
	C8-245	Filter	---	0.5	3	10	0.002
		Charcoal	---	0.3	9	10	
1/13-1/14	C8-215	Filter**	---	1	4	---	1.2
		Charcoal	---	---	3	---	
	C8-230	Filter	---	1	---	---	1
		Charcoal	---	---	6.8	7.6	
	C8-245	Filter**	---	---	---	---	0.01
		Charcoal	---	---	12	32	
	C4-230	Filter	---	1	2	---	2.1
		Charcoal	---	0.2	14	9	

*A dash (---) indicates non-detectable levels.

**These two samplers stopped during sampling period. A reasonable estimate of total flow was made based on knowledge of normal fuel consumption.

2. Other Sampling

The data for the fallout trays, soil, vegetation, hay samples and film badges are tabulated in Table 13 for the fixed stations and in Table 14 for the mobile station. The air sampler results are shown for comparison. All the data are corrected to the time of collection or end-point of collection period for air samples. The air sampler data are in units of pCi/m^3 and the hay, vegetation and soil samples in units of pCi/kg. The counting error in these samples is 100 pCi/kg or 10%, whichever is greater. The fallout trays were both gamma scanned and beta counted with the results expressed in units of pCi/m^2.

The film badge results in Table 13 represent the integrated exposure in mR for the 48 hour period following the event. All control badges, and those in place at the stations for 24 hours before the test, registered < 20 mR.

The survey meter readings taken at the fixed stations are shown in Table 15. The readings at all 8 stakes were averaged as were the readings at five positions on the stack of baled hay and the pile of loose hay. The gamma readings at the stakes were taken at 3 feet above ground and the beta plus gamma readings at ground level. For the hay, both types of readings were taken at the surface of the hay.

The high volume sampler prefilter at station C4-230 indicated a beryllium concentration of $.03\,\mu g/m^3$ while that at station C8-215 indicated $.015\,\mu g/m^3$. These analyses were performed by the Analytical Radiochemistry Laboratory of Reynolds Electrical and Engineering Co.

Table 13. Environmental sample results at fixed stations on January 12, 1965.

Location	Sample	^{131}I	^{132}I	^{133}I	^{135}I	Film Badge	Gross Beta	pCi-sec/m^3
C4-230	HV filter (pCi/m^3)						9	11x10^4
	LV filter (pCi/m^3)						490	59x10^5
	HV charcoal (pCi/m^3)	---	22	550	4,000			55x10^6
	LV charcoal (pCi/m^3)	---	75	130	5,200			65x10^6
	Fallout tray (pCi/m^2)	---	220,000	130,000	31,000		500,000	
	Loose hay (pCi/kg)	---	3,100	2,700	64,000			
	Baled hay-top (pCi/kg)	---	740	920	9,200			
	Baled hay-front (pCi/kg)	---	2,300	3,600	23,000			
	Avg. 4 film badges (mR)					438		
C8-215	HV filter (pCi/m^3)						6,000	16x10^7
	LV filter (pCi/m^3)						6,000	16x10^7
	HV charcoal (pCi/m^3)	---	270	900	4,500			15x10^7
	LV charcoal (pCi/m^3)	---	76	130	3,000			85x10^6
	Fallout tray (pCi/m^2)	---	680,000	---	---		11,000,000	
	Loose hay (pCi/kg)	---	4,800,000	160,000	33,000			
	Baled hay-top (pCi/kg)	---	2,300	2,200	3,300			
	Baled hay-front (pCi/kg)	---	---	---	---			
	Avg. 4 film badges (mR)					324		
	Vegetation (pCi/kg)	---	620,000	3,200,000	1,400,000			
	Soil (pCi/kg)	---	470,000	34,000	240,000			

(continued)

Table 13. Environmental sample results at fixed stations on January 12, 1965. (continued)

Location	Sample	^{131}I	^{132}I	^{133}I	^{135}I	Film Badge	Gross Beta	pCi-sec/m^3
C8-230	HV filter (pCi/m^3)						840	$25x10^6$
	LV filter (pCi/m^3)						610	$18x10^6$
	HV charcoal (pCi/m^3)	---	11	84	1,700			$53x10^6$
	LV charcoal (pCi/m^3)	---	9	---	810			$24x10^6$
	Fallout tray (pCi/m^2)	---	24,000	37,000	190,000		61,000	
	Loose hay (pCi/kg)	---	3,000	2,000	1,300,000			
	Baled hay-front (pCi/kg)	---	---	---	---			
	Avg. 4 film badges (mR)					34		
	Vegetation (pCi/kg)	---	75,000	180,000	1,500,000			
	Soil (pCi/kg)	---	2,000	2,000	4,000			
C8-245	HV filter (pCi/m^3)						47	$15x10^5$
	LV filter (pCi/m^3)						11	$35x10^4$
	HV charcoal (pCi/m^3)	---	2	31	81			$36x10^5$
	LV charcoal (pCi/m^3)	---	---	18	---			$57x10^4$
	Fallout tray (pCi/m^2)	---	9,500	27,000	---		15,000	
	Loose hay (pCi/kg)	---	500	4,000	6,000			
	Baled hay-front (pCi/kg)	---	---	---	---			
	Avg. 4 film badges (mR)					< 20		
	Vegetation (pCi/kg)	---	---	---	---			
	Soil (pCi/kg)	---	---	710	---			

A dash(---) indicates non-detectable levels. A blank indicates no measurement attempted.
HV = High volume.
LV = Low volume.

Table 14. Environmental sample results at the mobile station* on January 12, 1965.

Sample	^{131}I	^{132}I	^{133}I	^{135}I	Beta	pCi-sec/m^3
HV filter (pCi/m^3)					32,000	15x10^7
LV filter (pCi/m^3)					20,000	72x10^6
HV charcoal (pCi/m^3)	---	130	300	300		34x10^5
LV charcoal (pCi/m^3)	---	140	310	1,700		77x10^5
Baled hay (surface layer) (pCi/kg)	---	1,000	1,000	1,400		
Vegetation (pCi/kg)	---	---	---	---		
Soil (pCi/kg)	---	4,000	1,600	4,000		
Fallout tray (pCi/m^2)	---	70,000	---	---	120,000	

*Approximately 16 miles from Test Cell C near Lathrop Wells.
A dash (---) indicates non-detectable levels.
HV = High volume
LV = Low volume

Table 15. Survey meter readings.

Location		Gamma mR/hr				Beta + Gamma mR/hr		
		Before	3 hr.	24 hr.	48 hr.	3 hr.	24 hr.	48 hr.
C4-230	Stakes	.025	0.6	.06	.04	1.1	0.13	.06
	Baled Hay		0.8	.08	.04			
	Loose Hay		0.75					
C8-215	Stakes	.02	2.7	0.38	0.16	9.3	1.8	0.8
	Baled Hay		2.6	0.3	0.2			
	Loose Hay		3.8					
C8-230	Stakes	.03	.07	.03		0.22	.06	
	Baled Hay		.10	.04				
	Loose Hay		.09					
C8-245	Stakes	.025	.045	.03		0.10	.04	
	Baled Hay		.03	.03				
	Loose Hay		.03					

Near Lathrop Wells, ground surface, peak Beta + Gamma reading of 18 mR/hr during cloud passage.

The radioiodine data from the soil and vegetation samples are presented in Table 16. Samples were taken on the day of the test and one week later to determine the decay on these samples. Additional samples were taken, after an over-night rain, to determine the effect of the rain.

C. Discussion

The use of two types of air samplers at each sampling location was an attempt to determine which was more efficient for detecting radioiodines in fallout clouds. The data in Table 11 indicate that the high volume sampler was more efficient for radioiodines at the 8000 foot arc, the low volume was somewhat better at the 4000 foot arc, but there was little difference, if any, between them at 16 miles from Test Cell C.

The major purpose of the environmental sampling studies was to seek to obtain correlations so that a determination could be made as to which type of sample would be best to use as an immediate indicator of expected radioiodine levels in cow's milk in this test situation. Unfortunately none of the samples collected a few hours after the test contained detectable quantities of ^{131}I.

A tabulation showing the ratio of the results at station C8-215 to those at station C4-230 is shown in Table 17. The ratios that are closest to the peak milk activity ratios are the gamma activity in the fallout tray, the gamma activity in the charcoal from the low volume air samplers and the film badge exposure. In case of an unexpected release, though, none of these types of samples would be collected; thus the samples of choice would have to be milk or forage from the area. The difficulty in getting a representative sample of forage is indicated by the peak ^{131}I levels in the loose hay. The ^{131}I peak activity in the hay from one

Table 16. Soil and vegetation sampling results (pCi/kg) for indicated dates.

Location	^{131}I			^{132}I			^{133}I		
	1/12	1/19	1/20*	1/12	1/19	1/20*	1/12	1/19	1/20*
				SOIL					
C4-230		18,000	1,200		---	540		---	---
C8-215	---	17,000	1,300	470,000	---	470	34,000	15,000	510
C8-230	---	16,000	2,000	2,100	---	1,700	1,700	---	1,500
				VEGETATION					
C4-230		30,000	8,000		39,000	7,900		71,000	5,000
C8-215	---	53,000	3,000	620,000	70,000	3,000	3,200,000	140,000	2,000
C8-230	---	10,000	22,000	75,000	13,000	28,000	180,000	27,000	28,000

*Samples taken this date after a 0.19" rainfall.

A dash (---) indicates non-detectable levels.

A blank indicates no measurement made.

station was three times as high as that from the other station, but the peaks in the milk from cows fed the hay were nearly the same. The previous statement does not hold for ^{133}I activities.

Table 17. Activity ratios of various samples.

SAMPLE TYPE	RATIO C8-215/C4-230
Peak ^{131}I in milk - single cow	1.15
Peak ^{131}I in milk - group average	1.03
Peak ^{131}I in loose hay	3.2
Peak ^{133}I in milk - single cow	1.00
Peak ^{133}I in milk - group average	0.86
Peak ^{133}I in loose hay	0.58
Gamma activity - fallout tray	1.8
Beta activity - high volume filter	1,400
Beta activity - low volume filter	27
Gamma activity - high volume charcoal	2.7
Gamma activity - low volume charcoal	1.3
Gamma mR/hr at 3 feet and 3 hours	4.5
Beta and gamma mR/hr on ground at 3 hours	8.4
Film badge exposure - mR/48 hr.	0.73

Though soil samples were collected and gamma scanned, no great confidence is placed in these data because of the difficulty in obtaining reproducible and uniform samples. To some extent, the same consideration applies to the vegetation. Though an attempt was made to maximize the amount of leaf material in all samples, the ratio by weight of leaves to stems and area of ground covered could not be accurately controlled. The ^{131}I in soil (Table 16) decreased by factors of 8 to 15 after an overnight rain amounting to 0.19 inch. The decrease in the ^{131}I on vegetation at stations C4-230 and C8-215 caused by the rain tends to confirm the results of the hay study mentioned in Section III of this report. The reason for the increased levels of the three radioiodines in the vegetation of station C8-230 after the rain is unknown.

VI. SPECIAL RADIOIODINE AIR SAMPLER STUDY

A. Procedure

Several types of air sampling equipment were assembled for this test in an attempt to sample all forms of iodine that might be present in the cloud. Other samplers used, e.g., the high volume and low volume samplers reported in Section V of this report, retain unknown fractions of organic iodides or of submicron particulates which may be present in the cloud. In general, each experimental assembly was paralleled with a prefilter-charcoal cartridge sampler to permit comparison of efficiencies.

Diagrams of the sampling systems are shown in Figure 11. Electrostatic precipitators were used to remove submicron particulates. The electrofilter in system 4 performs the same function and it, like the spark chambers, will break down organic iodides which can then be collected on resin. The resin used in the systems was Dowex 1 x 8, 50-100 mesh.

System 1 was located at C4-230 and system 2 was located at C8-230. System 3 was placed at C4-230 with system 1 and both were controlled by a radiation monitoring device which turned them on when the background rose to 1 mR/hr. They were timed to operate for two hours. System 2 was started just before the area was cleared and ran eleven hours before being stopped. System 4 was mounted in a truck and was driven into the path of the cloud about 16 miles from Test Cell C. It was operated during cloud passage and for about two hours afterwards to flush xenon from the system.

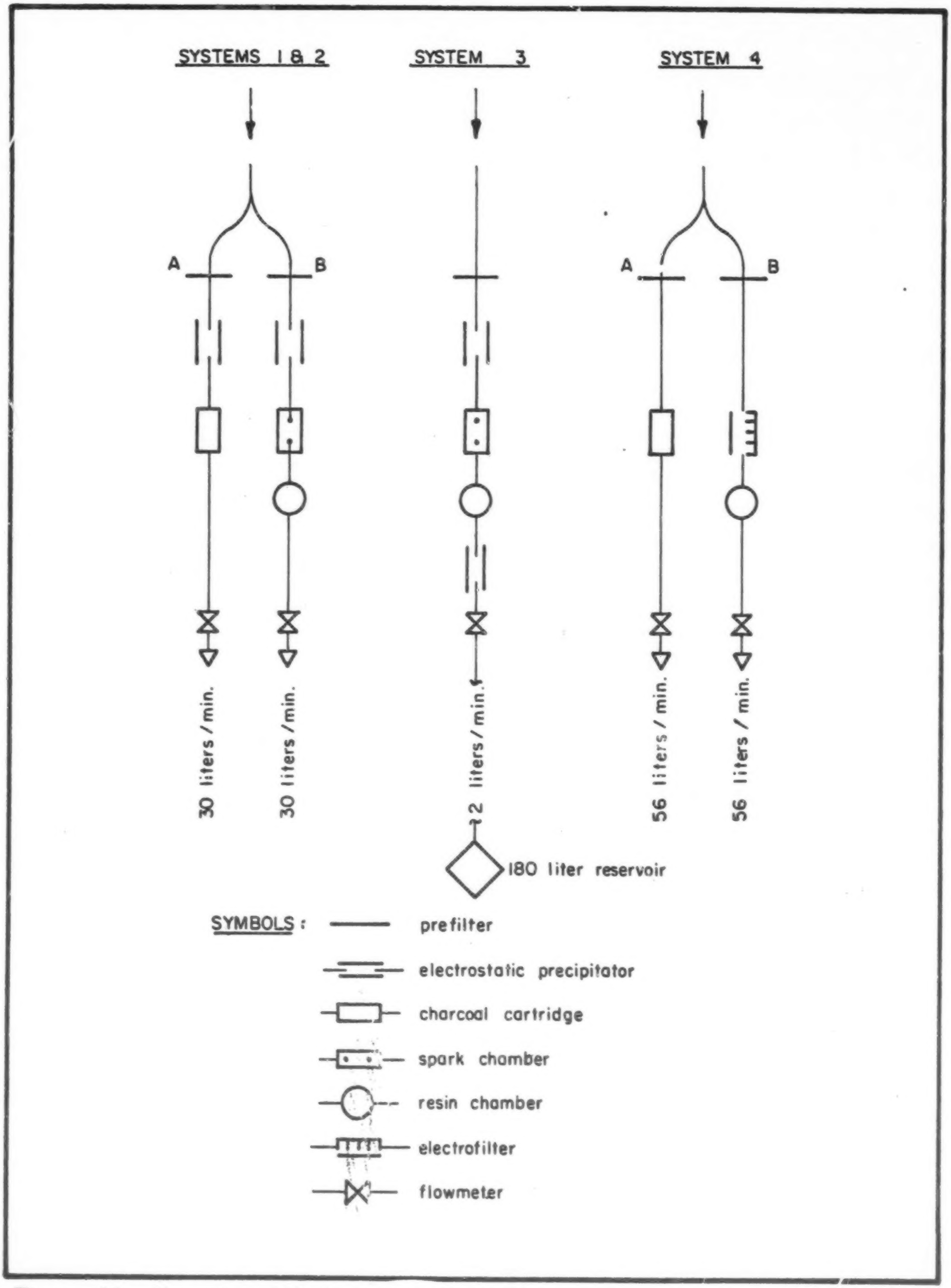
SYSTEMS 1 & 2
SYSTEM 3
SYSTEM 4
A
B
A
B
30 liters / min.
30 liters / min.
2 liters / min.
56 liters / min.
56 liters / min.
180 liter reservoir
SYMBOLS:
prefilter
electrostatic precipitator
charcoal cartridge
spark chamber
resin chamber
electrofilter
flowmeter

Figure 11. Experimental air samplers.

The effluent from system 3 was collected in a 180-liter reservoir. A group of 10 rats was allowed to breathe this effluent air, sacrificed 48 hours later and the radioiodine activity in the pooled thyroids was then determined. Another group of 10 rats was placed in a cage at the same location as system 3 and allowed to breathe atmospheric air during cloud passage. This group was also sacrificed after 48 hours and the radioiodine activity in the pooled thyroids determined. The ratio of thyroid activities between the two groups should indicate the relative efficiency with which system 3 removed biologically available radioiodine from the cloud.

B. Results and Discussion

The four systems used for this experiment were assembled in the laboratory and transported to the field. In this process some of the connections between various elements of the air samplers were loosened sufficiently to allow leakage which resulted in anomalous data. The samplers have worked satisfactorily using aerosols generated in the laboratory but must be rebuilt to withstand transport under field conditions. The rat experiment yielded useful data. The pooled thyroids of the 10 rats allowed to breathe atmospheric air during cloud passage yielded a net beta activity of 242 cpm compared to a net beta activity of 1 cpm for the pooled thyroids of the rats allowed to breathe the 180 liters of air after passage through system 3. Thus, system 3 was apparently better than 99% efficient for removal of biologically available radioiodines from the TNT effluent. This assumes that the 18-minute exposure to the filtered air of one group of rats was equivalent to the exposure of the other group of rats during cloud passage. Eighteen minutes is probably a realistic estimate of cloud duration at 4000 feet from Test Cell C.

VII. DISCUSSION OF TOTAL STUDY

Before beginning a detailed discussion of this study, it seems appropriate to compare some of the results with those of other groups involved in the TNT test as a check on the procedures used by our group. The report by the LASL H-8 Group contains results of their environmental monitoring.[1] Table 18 lists results as published in that report and similar data from this study. All our sample results were extrapolated to the end-point of collection time whereas the H-8 results were corrected to H+1000 minutes. Thus a direct comparison of the different results is not possible.

The objectives listed in Section I of this report were achieved to the extent indicated below.

1. For the forms of radioiodines present in the TNT effluent, the loosely piled hay retained more activity per kilogram than the stacked, baled hay. This was probably due to the higher surface area which the loosely piled hay presented to the fallout cloud. The fact that no activity was detectable at depths greater than three inches from the surface of the baled hay indicates that penetration of aerosols into a bale was negligible. At C4-230 some penetration between bales was observed and also greater deposition was observed on the vertical hay surface of the stack than on the horizontal surface. At C8-215 no measurable contamination was found on the vertical hay surface of the stack.

2. The ^{131}I levels in the milk of the cows fed the contaminated loose hay from stations C4-230 and C8-215 followed the general course of other studies as indicated in Table 19. The peak levels occurred about 48 hours after the initial hay feeding. During continued feeding of the hay, the average effective half-life in Group I

Table 18. Environmental sampling: comparison of this study with LASL H-8 results.

Sample	Location	This Study	H-8 Group*	Units
Gaseous air	C4-230	55×10^6	$10^8 - 10^9$	pCi-sec/m^3
Gaseous air	C8-215	15×10^7	$10^7 - 10^8$	"
Gaseous air	Lathrop Wells	60×10^5	$10^6 - 10^7$	"
Fallout tray	C4-230	38×10^4	$10^6 - 10^7$	pCi/m^2
Fallout tray	C8-215	68×10^4	$10^6 - 10^7$	"
Fallout tray	Lathrop Wells	12×10^4	$10^6 - 10^7$	"
Particulate air	C4-230	60×10^5	$10^8 - 10^9$	pCi-sec/m^3
Particulate air	C8-215	16×10^7	$10^8 - 10^9$	"
Particulate air	C8-230	25×10^6	$10^6 - 10^7$	"
Particulate air	C8-245	15×10^5	$10^5 - 10^6$	"
Particulate air	Lathrop Wells	15×10^7	$10^6 - 10^7$	"
Gamma exposure	C4-230	438 mR		
Gamma exposure	C8-215	324 mR		

*These values were read from graphs of the data since the actual data were not included in the report. These results were corrected to H+1000 min. whereas ours were corrected to end-point of collection time.

Table 19. Comparison of this study with other studies.

Reference	Number of Cows	Liters per Day	Type of Feed	Days Fed	pCi/kg in Feed	Total Intake pCi	Total % in Milk	pCi/liter* / pCi/gm	Time to Peak-hours	T_{eff} during Ingestion days
This report	5	15.5	Hay	6	51×10^2	51×10^4	7.4	16	48	5.7
	5	16.6	Hay	6	16×10^2	13×10^4	22.6	50	48	2.9
3	3(Habbart)	10.5	Green chop		47×10^2			80	96	3.9
	24(Habbart)	16.4	Hay		13×10^2			54	72	5.9
	3(LDS)	6.1	Green chop		17×10^2			38	72	4.0
	97(LDS)	9.3	Hay		63×10^1			46	-	-
7	6	7.4	Pasture	15	77×10^5	10×10^7	4.7	240	48	5
5			Pasture		31×10^5			32	48	5
8			Pasture		13×10^3			22	96	2
9	9	12.4	Capsule	14		10×10^7			48-60	8
10			Pasture					150	144	8
12			Pasture					70		
13	3		Grain						96	9
11			Pasture					70	72	5
14	5	5.6	Pasture	16	16×10^3			16	48	7

*Milk to forage ratio of peak average values.

cows was 5.7 days while in Group II it was 2.9 days, and the effective half-life, after cessation of feeding, decreased to 1.7 and 1.2 days respectively.

The calculated biological half-lives for Group I cows were 19.8 days for ^{131}I and 6.3 days (4.1 - 14.5)* for ^{133}I. For Group II cows the corresponding values were 4.6 days for ^{131}I and 1.8 days (1.3 - 2.8) for ^{133}I. Confidence intervals are not given for the ^{131}I data since in each case the upper limit comes out to be infinite. Note that for the ^{133}I data the biological half-life ranges indicate no overlap which supports a conclusion that the biological clearances of the ^{133}I contaminants at the two stations were significantly different.

A major difference, compared to some other published data appears in the Group II effective half-life of ^{131}I in milk. The most likely reason for this difference is the variation in characteristics of the contaminants on the ingested material. Where the activity on the feed decreases only by physical decay (e.g., in references 9 and 13 in Table 19), the half-life in milk is reported as eight days. In other cases this half-life is less than eight days. It appears that 5 ± 2 days is a reasonable estimate for this factor when the contamination is on pasture or green chop. When the contamination is on hay, the effective half-life may or may not be the same as for fresh green forage. The average value of the peak activity per liter of milk divided by the peak activity on the feed is 45 for 11 of the 13 values listed in Table 19. Of the two values not considered in the average, the value of 240 was omitted because it resulted from a pure gaseous deposition and the 150 value was an average obtained from widely varying data. This ratio appears to hold even though the peak forage activity varied from 3μCi/kg to as low as

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*95% confidence interval

1.3 nCi/kg. The average observed value for this ratio for our two groups of experimental cows was 33. In general, our cows produced more milk than the others listed. In agreement with the work of Garner, et al[15] and Miller, et al[16], our data indicate a positive correlation of percent recovery of ingested dose with total milk production. This relationship is presented in Figure 12.

A slightly different way of approaching the ^{131}I data is shown in Figures 13 and 14. If the average milk concentration and total per day are calculated by using the p.m. milking after the contaminated feeding, plus the a.m. milking before the next contaminated feeding instead of the daily averages in which the a.m. and p.m. milkings bracket the feeding of contaminated hay, then the secretion curves appear different. The Group I cows show a relatively constant value of pCi/liter for four days and the peak value in both groups becomes identical. The peak occurs at 58 hours after the initial feeding in Group I but only 34 hours after initial feeding in Group II. This may be a more valid way of examining the data and suggests that Group II cows were more efficient in terms of total quantities and rates in incorporating radioiodine into their milk than Group I cows (higher percent output on lower intake, but nearly equal peak pCi/liter in Group II compared to Group I).

The ^{131}I differences between the two groups of cows may be partially due to sampling errors in not obtaining representative samples of the hay actually ingested. There is also some doubt about the adequacy of the analytical procedures for the hay samples. Future studies will incorporate improved techniques. The possibility that the nature of the radioiodine contamination at C4-230 differed markedly from that at C8-215 also cannot be overlooked (see 5 below).

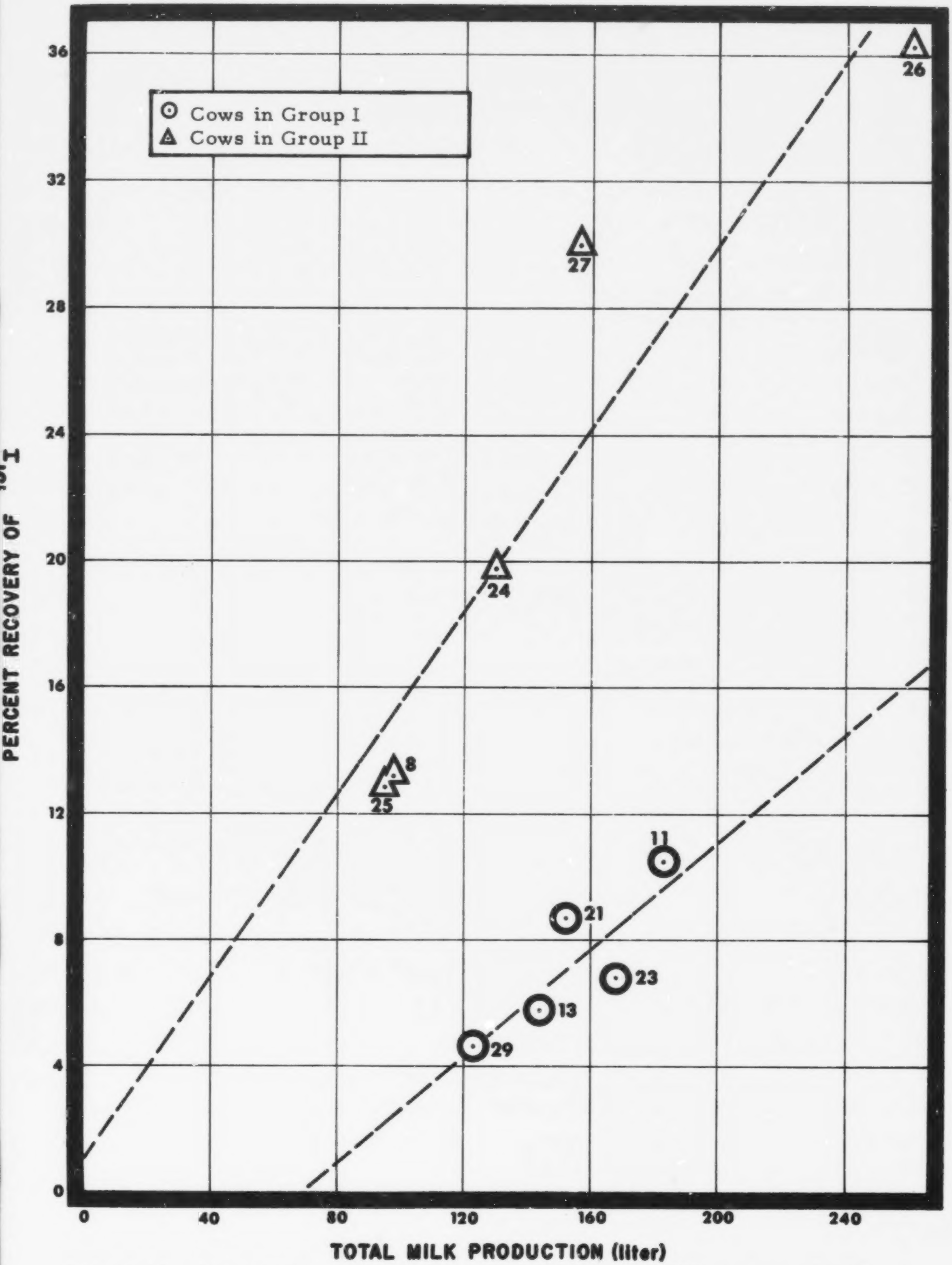

Figure 12. Relationship between percentage of ingested ^{131}I recovered and total milk yield.

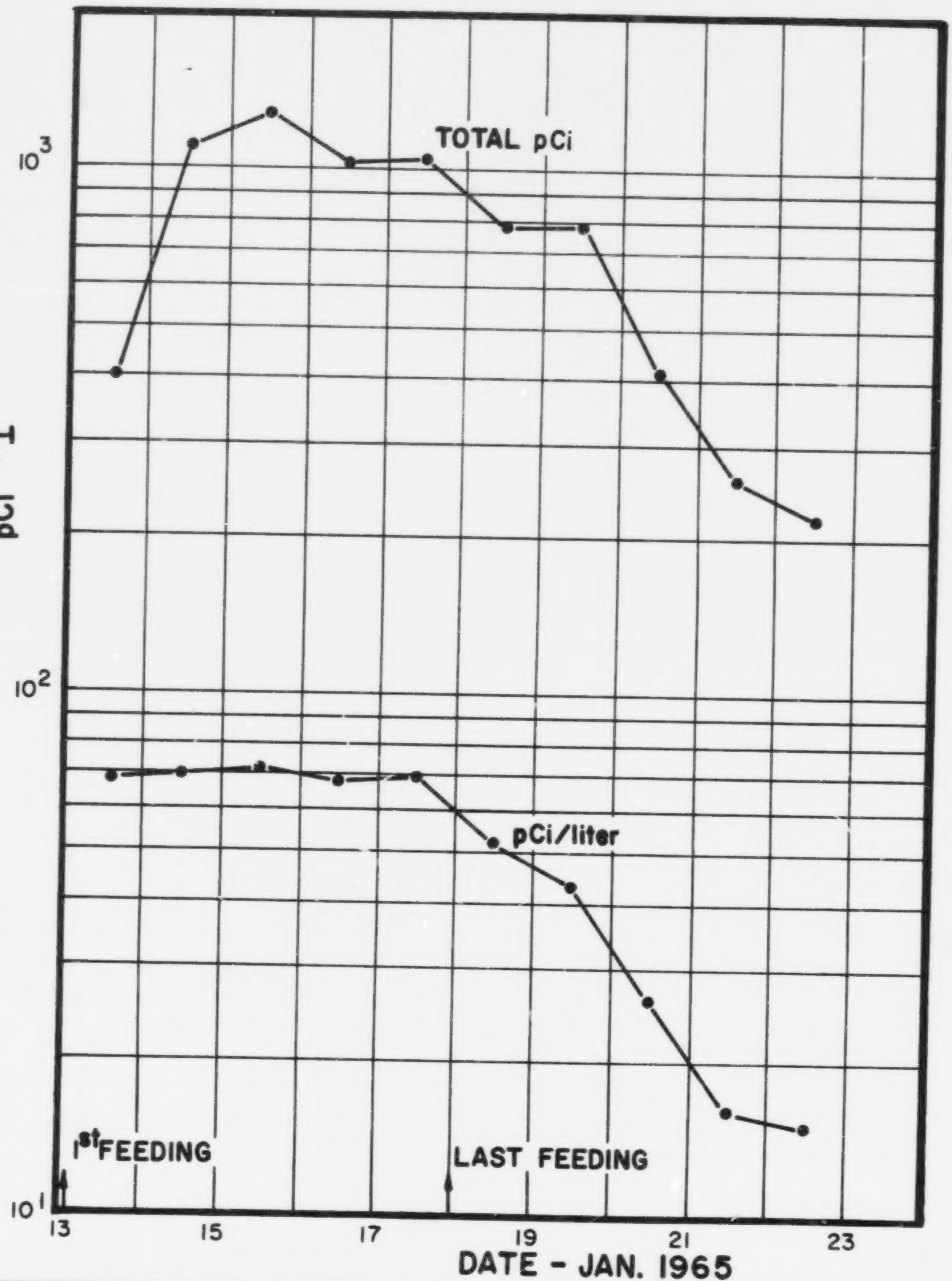

Figure 13. Average of a. m. and p. m. milk taken between feedings for Group I cows.

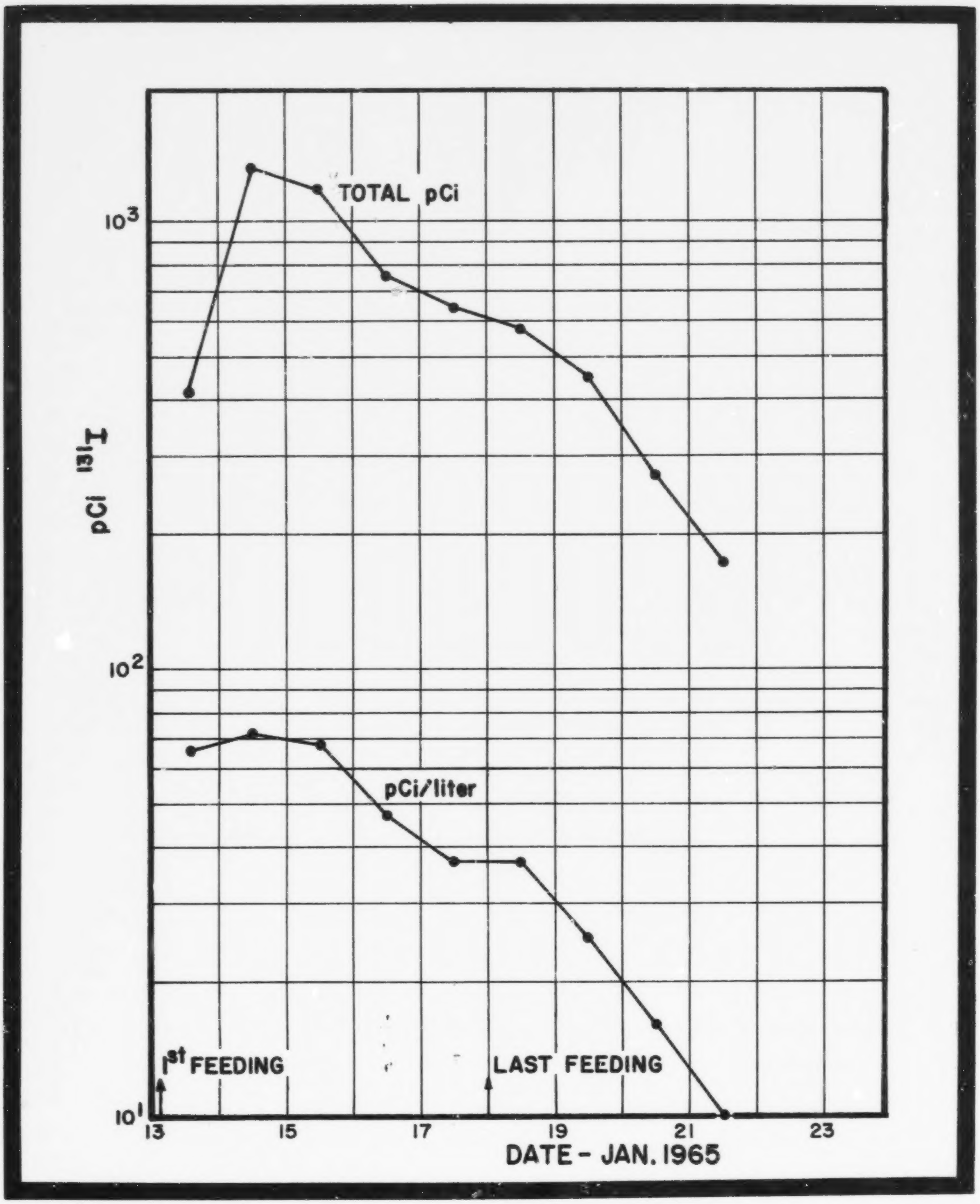

Table 14. Average of a.m. and p.m. milk taken between feedings for Group II cows.

3. The relative efficiencies of the high volume and low volume samplers used in this study indicate little difference between the two types of air sampler under the conditions of this study. The idea behind the study was that elution of radioiodine from charcoal, if it occurs, would be greater for the high volume air sampler. If this were true, the low volume sampler would give a higher pCi/m^3 result and would more nearly represent the true air concentration of gaseous radioiodines. This idea was not substantiated in this study, at least for the type of effluent generated by TNT. This type of experiment will be continued in future studies with comparison samples being taken from different types of contaminated aerosols at different points in time and location.

4. For the conditions of this experiment the air sampling device designed to remove all biologically available radioiodine was successfully field tested. Further tests of this device must be conducted before we will feel confident that we have developed an air sampling train which removes essentially all biologically available radioiodine.

5. Much information was accumulated from the environmental studies but most of it was difficult to interpret. Ratios of results between types of samples were not consistent enough for valid comparisons. It is felt that most of the difficulty lies in the sampling procedures. Undoubtedly there should be some correlation among all the types of samples collected if the samples were truly representative. Based on this experience, methods of collecting various samples are being refined for use in future studies. Indigenous vegetation sampling, though, will be difficult to improve to any great extent because of the difficulty of collecting desert vegetation which accurately represents a given area of ground or a given leaf surface area exposed to the effluent.

As indicated previously, our measured contamination levels in the hay fed to each group of cows exhibited such spread that we were forced to use a smoothing technique on these data. In view of this, all results involving these hay data should be viewed as qualitative pending future studies where improved sampling techniques will be utilized.

Our air sampling data indicated that the gaseous/particulate ratio of activities at C8-215 was one tenth that at C4-230. This finding was confirmed by other reported data.[1] In view of this, it is believed that the studies relating to each station should be viewed as two separate studies with no attempt being made to correlate the results at C4-230 with those at C8-215. The apparently different effective half-lives of the ^{131}I activity in the milk of cows consuming contaminated forage from each station tends to bear this out as do the calculated biological half-lives (T_{biol}) for ^{131}I and ^{133}I for each group of cows. It appears that the more gaseous contaminant tends to disappear from milk at a more rapid rate. For comparison to past results it is believed that the gaseous/particulate ratio at C8-215 was more typical of a contaminating event such as Pike[3]. In particular, the effective half-life of ^{131}I in the milk of cows eating contaminated hay from C8-215, 5.7 days, agrees quite well with a corresponding value measured following Pike, 5.9 days.

VIII. SUMMARY AND CONCLUSIONS

In summary, the findings with regard to each stated objective are presented below:

1. Radioiodines in the effluent contaminated the loosely piled hay to a greater extent than stacked, baled hay on a per kilogram basis. Radioiodines did not penetrate individual bales of hay but did penetrate the stack between bales at one station. Radioiodines are relatively loosely attached to hay initially, but a small fraction of the total activity is relatively firmly attached at later times. The data for determination of effective half-life of ^{131}I on hay was so variable that no confidence can be placed on the results.

2. Table 20 presents a summary of the milk sampling results. For individual cows a positive correlation exists between percent recovery of ^{131}I ingested dose and total milk production.

3. The relative efficiencies of high volume and low volume air samplers for the collection of radioiodines varied considerably at different locations. With one possible notable exception at a location where the radioiodines were more gaseous in nature, the high volume samplers appeared to be as efficient or more efficient than the low volume samplers. Further study of this matter is indicated.

4. The air sampling device designed to remove all biologically available radioiodine did remove in excess of 99 percent of the biologically available radioiodine. However, further study of this device under a variety of experimental conditions is indicated.

Table 20. Summary of milk sampling results.

Number of Cows	Liters per Day	Days Fed	Total Intake (pCi)	Total % Milk	Peak $\frac{\text{pCi/liter}}{\text{pCi/gram hay}}$	Time to Peak (hours)	T_{eff} During Ingestion	T_{eff} After Ingestion (days)	T_{biol} During Ingestion (days)
Group I: 5	15.5	6	$^{131}I \rightarrow 51 \times 10^4$	7.4	16	48	5.7 days	1.7	19.8
			$^{133}I \rightarrow 70 \times 10^4$	6.0	54	12	18.3 hrs.		6.3
Group II: 5	16.6	6	$^{131}I \rightarrow 13 \times 10^4$	22.6	50	48	2.9 days	1.2	4.6
			$^{133}I \rightarrow 67 \times 10^4$	7.7	38	12	14.0 hrs.		1.8

5. Ratios of activities between various types of environmental samples were not consistent enough for valid comparisons. Air sampling results did indicate, however, that the contaminant at the station closest to the source was more gaseous in nature than at the more distant station.

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APPENDIX

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Table 1a. Experimental data on Group I cows fed loose hay from station C8-215. Cow No. 11

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results - pCi/kg		Milk Sample Results - pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0610	10.0	6,000	50		20				
1/14	0240	7.7	5,000	7,000		40	830	100	14	6.2
	1610				2.0	25	340	70	19	8.4
1/15	0610	8.6	50	50	4.0	50	270	130	24.5	10.9
	1610				3.0	30	190	100	17	7.5
1/16	0610	8.2	50	2,900	3.0	25	90	90	33	14.6
	1510				3.0	10	50	120	15	6.6
1/17	0610	9.5	3,000	1,200	2.0	40	30	80	26	11.5
	1510				3.0	35	40	100	15	6.6
1/18	0610	9.5	50	1,400	1.0	25	10	80	28	12.4
	1710				2.0	20	10	80	17	7.5
1/19	0610				4.0	30		50	19	8.3
	1610				1.0	30		40	20	8.9
1/20	0610				3.0	30		20	32	14.2
	1610				2.0	30		40	18	8.0
1/21	0610				3.0	25		10	28	12.4
	1610				4.0	25		30	15	6.6
1/22	0610				2.0	35		30	29	12.8
	1500				3.0	30		10	16	7.1
1/23	0610				2.0	25		10	28	12.4
	1510				1.0	35			15	6.6
1/24	0610				3.0	25			34	15.1
	1510				3.0	30			13	5.8
1/25	0610					25			26	11.5

Table 1b. Experimental data on Group I cows fed loose hay from station C8-215. Cow No. 13

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0620	5.9	9,600	50						
1/14	0250	8.9	50	3,900		20	180	70	12	5.3
	1620				2.0	35	110	40	15	6.6
1/15	0620	9.3	50	50	3.0	30	120	60	18	8.0
	1620				3.0	15	70	60	15	6.6
1/16	0620	7.7	2,800	2,600	4.0	15	20	40	22	9.7
	1520				2.0	25	30	60	12.5	5.5
1/17	0620	6.4	2,800	50	1.0	30	30	40	20	8.9
	1520				3.0	25	10	50	13	5.8
1/18	0620	9.1	2,200	1,100	6.0	30	10	40	22	9.7
	1720				5.0	40		40	12	5.3
1/19	0620				3.0	25		40	16	7.1
	1620				1.0	30		50	14	6.2
1/20	0620				2.0	30		30	22	9.7
	1620				1.0	30		20	13	5.8
1/21	0620				1.0	30		30	21	9.3
	1620				1.0	25		20	11	4.9
1/22	0620				1.0	25		10	24	10.9
	1520				3.0	25		20	11	4.9
1/23	0620				3.0	15		10	18	8.0
	1520				1.0	60		10	14	6.2
1/24	0620				4.0	25			22	9.7
	1520				3.0	15			11	4.9
1/25	0620				3.0	30			22	9.7

Table 1c. Experimental data on Group I cows fed loose hay from station C8-215. Cow No. 21

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0630	7.7	6,000	6,100		25				
1/14	0300	8.2	50	50		45	370	60	12.5	5.5
	1630				5.0	35	270	80	12.5	5.5
1/15	0630	8.6	50	50	2.0	25	170	90	24	10.9
	1630				4.0	30	110	150	13	5.8
1/16	0630	7.7	50	50	4.0	35	110	100	25	11.1
	1530				3.0	20	70	120	11	4.9
1/17	0630	8.2	50	2,200	3.0	25	30	70	22	9.7
	1530				2.0	25	30	90	13	5.8
1/18	0630	10.0	50	50	1.0	20	10	60	22	12.3
	1730				3.0	60	10	70	13	5.8
1/19	0630				4.0	20		30	17	7.5
	1630				2.0	35		80	19	8.4
1/20	0630				15.0	40		40	24	10.9
	1630				3.0	30		30	12	5.3
1/21	0630				5.0	25		30	18	8.0
	1630				5.0	35		30	10	4.4
1/22	0630				4.0	25		10	25	11.1
	1530				5.0	35		30	13	5.8
1/23	0630				5.0	10		10	22	9.7
	1530				3.0	35		10	14	6.2
1/24	0630				4.0	30			24	10.9
	1530				4.0	10			12	5.3
1/25	0630				4.0	15			25	11.1

Table 1d. Experimental data on Group I cows fed loose hay from station C8-215. Cow No. 23

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0640	9.5	5,800	50		10				
1/14	0310	9.5	15,000	50		45	540	70	15	6.6
	1640				1.0	40	290	50	21	9.3
1/15	0640	8.6	50	50	2.0	25	140	90	23	10.2
	1640				4.0	25	80	60	23	10.2
1/16	0640	9.5	3,000	2,600	4.0	25	70	70	27	12.0
	1540				1.0	30	60	70	12	5.3
1/17	0640	9.5	3,800	2,100	1.0	25	10	60	25	11.1
	1540				3.0	25	30	110	14	6.2
1/18	0640	10.0		50		25	10	60	9	4.0
	1740				1.0	20	10	50	18	8.0
1/19	0640					10		50	18	8.0
	1640					30		40	19	8.4
1/20	0640				1.0	35		50	29	12.8
	1640				1.0	20		40	13	5.8
1/21	0640				1.0	25		20	28	12.4
	1640				3.0	25		10	11	4.9
1/22	0640				2.0	25		10	25	11.1
	1540				3.0	30		20	12	5.3
1/23	0640				3.0	25		10	21	9.3
	1540				1.0	20		10	17	7.5
1/24	0640				1.0	20			31	13.7
	1540				2.0	10			14	6.2
1/25	0640				2.0	15			29	12.8

Table 1e. Experimental data on Group I cows fed loose hay from station C8-215. Cow No. 29

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0650	9.5	10,000	50		20				
1/14	0320	7.3	50	11,000		50	410	40	12	5.3
	1650				1.0	35	230	40	13	5.8
1/15	0650	8.6	50	50	5.0	35	90	40	10	4.4
	1650				3.0	15	70	40	15	6.6
1/16	0650	5.4	4,600	3,000	3.0	30	30	30	13.5	6.0
	1550				2.0	40	40	50	15	6.6
1/17	0650	9.5	6,700	7,900	2.0	40	20	40	12.5	5.5
	1550				1.0	20	10	90	13	5.8
1/18	0650	9.5	1,100	4,800	2.0	25	10	30	15	6.6
	1750				3.0	15		50	11	4.9
1/19	0650				5.0	30		60	15	6.6
	1650				2.0	30		70	7	3.1
1/20	0650				3.0	35		40	23	10.2
	1650				1.0	40		40	12	5.3
1/21	0650				2.0	30		20	18	8.0
	1650				4.0	30		20	10	4.4
1/22	0650				2.0	25		10	24	10.9
	1550				2.0	25		20	10	4.4
1/23	0650				2.0	10		20	15	6.6
	1550				3.0	20		10	13	5.8
1/24	0650				2.0	15			20	8.9
	1550				2.0	25			12	5.3
1/25	0650				2.0	10			21	9.3

Table 1f. Experimental data on Group I cows fed loose hay from station C8-215. Cow No. 1

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0600	10.0	50	50		30				
1/14	0230	10.0	1,000	8,700		70	610	80	4	1.8
	1600				1.0	15	340	70	11	4.9
1/15	0600	10.0	50	50	1.0	50	240	130	8	3.5
	1600				1.0	15	260	120	10	4.4
1/16	0600	9.5	50	1,600	2.0	35	230	120	14	6.2
	1500				1.0	10	80	120	12	5.3
1/17	0600	9.5	50	50	1.0	30	50	100	11	4.9
	1500				2.0	25	10	80	9	4.0
1/18	0600	9.5	8,500	1,800		35	20	100	17	7.5
	1700					10	10	100	9	4.0
1/19	0600				2.0	30	10	80	10	4.4
	1600				1.0	25		90	10	4.4
1/20	0600					60		100	17	7.5
	1600				2.0	35		40	10	4.4
1/21	0600				1.0	25		20	21	9.3
	1600				2.0	5		10	7	3.1
1/22	0600				2.0			10	20	8.9
	1500				1.0			10	9	4.0
1/23	0600				1.0	25		20	18	8.0
	1500				1.0			10	10	4.4
1/24	0600								21	9.3
	1500					15			10	4.4
1/25	0600					30			18	8.0

Table 21. Experimental data on Group II cows fed loose hay from station C4-230. Cow No. 8

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0605	10.0	12,000	50		20				
1/14	0235	8.2	50	50		40	460	60	11	4.9
	1605				3.0	20	270	50	14	6.2
1/15	0605	9.1	50	50	3.0	35	210	70	14	6.2
	1605				4.0	35	140	80	6	2.7
1/16	0605	7.3	50	50	4.0	30	70	40	22	9.7
	1505				4.0	15	40	30	9	4.0
1/17	0605	5.9		50	2.0	20	20	40	15	6.6
	1505				2.0	20	10	30	8	3.5
1/18	0605	9.1		50	3.0	25	10	30	19	8.4
	1705				3.0	30		30	12	5.3
1/19	0605				3.0	30		50	15	6.6
	1605				3.0	10		10	11	4.9
1/20	0605				1.0	25		20	21	9.3
	1605				2.0	25		20	11	4.9
1/21	0605				2.0	10		10	21	9.3
	1605				3.0	15		10	12	5.3
1/22	0605				2.0	5			20	8.9
	1505				4.0	25			11	4.9
1/23	0605				5.0	35			22	9.7
	1505				2.0				15	6.6
1/24	0605				3.0	5			24	10.6
	1505				2.0	10			11	4.9
1/25	0605				1.0	5			21	9.3

Table 2b. Experimental data on Group II cows fed loose hay from station C4-230. Cow No. 24

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0615	10.0	11,000	50		25				
1/14	0245	9.5	50	50		35	500	60	12	5.3
	1615				2.0	15	200	50	17.5	7.8
1/15	0615	9.5	50	50	3.0	35	160	80	23	10.2
	1615				4.0	25	120	70	12	5.3
1/16	0615	8.2	50	50	3.0	35	60	70	28	12.4
	1515				4.0	75	10	50	13	5.8
1/17	0615	8.2		50	3.0	20	10	30	19	8.4
	1515				2.0	20		50	18	7.9
1/18	0615	9.1		50	3.0	15		30	22	9.7
	1715				2.0	20		50	18	8.0
1/19	0615				4.0	25		10	16	7.1
	1615				2.0	35		40	17	7.5
1/20	0615				3.0	15		10	24	10.6
	1615				2.0	35		40	14	6.2
1/21	0615				2.0	10		10	26	11.5
	1615				2.0	5		10	15	6.6
1/22	0615				1.0	30			30	13.3
	1515				3.0	15			13	5.8
1/23	0615				2.0	20			24	10.6
	1515				1.0	30			19	8.4
1/24	0615				3.0	15			27	12.0
	1515				2.0	30			13	5.8
1/25	0615				2.0	10			28	12.4

Table 2c. Experimental data on Group II cows fed loose hay from station C4-230. Cow No. 25

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results -pCi/kg		Milk Sample Results -pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0625	10.0	12,000	2,100		10				
1/14	0255	9.5	50	50		20	530	60	8	3.5
	1625				1.0	40	280	50	13	5.8
1/15	0625	9.5	50	50	1.0	25	160	80	13	5.8
	1625				3.0	20	110	60	11	4.9
1/16	0625	9.1	50	50	2.0	40	60	60	15	6.6
	1525				5.0	35	60	70	11	4.9
1/17	0625	8.2		50	2.0	30	10	30	16	7.1
	1525				2.0	30	10	60	11	4.9
1/18	0625	9.5		50	2.0	15		20	17	7.5
	1725				2.0	15		30	10	4.4
1/19	0625				2.0	20		40	12	5.3
	1625				3.0	20		30	8	3.5
1/20	0625				2.0	5		10	22	9.7
	1625				3.0	15		10	8	3.5
1/21	0625				4.0	30		20	15	6.6
	1625				3.0	10		10	10	4.4
1/22	0625				3.0	20		10	14	6.2
	1525								5	2.2
1/23	0625				1.0	15			15	6.6
	1525				2.0	25			10	4.4
1/24	0625				2.0				17	7.5
	1525				3.0	20			7	3.1
1/25	0625				2.0	15			18	8.0

Table 2d. Experimental data on Group II cows fed loose hay from station C4-230. Cow No. 26

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0635	10.0	9,200	5,000		30				
1/14	0305	9.1	6,100	1,900		40	500	70	26	11.5
	1635				4.0	35	330	60	29.5	13.1
1/15	0635	10.0	50	50	5.0	40	170	70	34.5	15.3
	1635				6.0	25	150	80	26	11.5
1/16	0635	7.7	50	50	5.0	40	80	80	33	14.6
	1535				6.0	25	60	90	22	9.7
1/17	0635	8.6		50	6.0	15	30	30	39	17.3
	1535				6.0	15	20	70	23	10.2
1/18	0635	9.5		3,400	5.0	35	10	20	37	16.4
	1735				5.0	25	10	40	27	12.0
1/19	0635				9.0	35		30	31	13.7
	1635				6.0	40		30	26	11.5
1/20	0635				11.0	25		10	31	13.7
	1635				8.0	30		20	24	10.6
1/21	0635				6.0	30		20	35	15.5
	1635				8.0	15		10	21	9.3
1/22	0635				6.0	35		10	41	18.2
	1535				10.0	40		20	24	10.6
1/23	0635				7.0	20		10	32	14.2
	1535				4.0	25		10	24	10.6
1/24	0635					35			35	15.5
	1535				3.0	15			20	8.9
1/25	0635				4.0	15			37	16.4

Table 2e. Experimental data on Group II cows fed loose hay from station C4-230. Cow No. 27

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0645	10.0	12,000	2,300		25				
1/14	0315	9.5	5,200	2,000		55	810	80	12.5	5.5
	1645				3.0	35	470	70	19	8.4
1/15	0645	10.0	50	50	3.0	40	250	120	30	13.3
	1645				3.0	15	170	70	15	6.6
1/16	0645	9.1	50	50	1.0	25	90	90	29	12.8
	1545				6.0	35	70	80	15	6.6
1/17	0645	8.2		50	2.0	20	10	50	23	10.2
	1545				2.0	20	10	60	16	7.1
1/18	0645	9.5		50	2.0	35		30	26	11.5
	1745				5.0	35		50	17	7.5
1/19	0645				4.0	35		40	17	7.5
	1645				3.0	35		60	17	7.5
1/20	0645				3.0	40		40	26	11.5
	1645				3.0	25		10	15	6.6
1/21	0645				1.0	25		10	25	11.1
	1645				3.0	25		20	7	3.1
1/22	0645				3.0	35		10	26	11.5
	1545				5.0	30		10	16	7.1
1/23	0645				3.0	35			25	11.1
	1545				3.0	15			16	7.1
1/24	0645				3.0	35			26	11.5
	1545				2.0	5			13	5.8
1/25	0645				3.0	15			27	12.0

Table 2f. Experimental data on Group II cows fed loose hay from station C4-230. Cow No. 28

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0655	10.0	7,800	50		25				
1/14	0300	9.5	6,000	1,700		70	650	60	2	0.9
	1655				1.0	35	330	50	4.5	2.0
1/15	0655	9.5	50	50	3.0	40	180	60	14	6.2
	1655				3.0	45	130	80	5	2.2
1/16	0655	7.7	50	50		25	60	40	10	4.4
	1555				1.0	35	40	50	4	1.8
1/17	0655	6.8		50	3.0	30	20	50	7	3.1
	1555				2.0	25	10	50	6	2.7
1/18	0655	9.1		50	2.0	30	10	30	9	4.0
	1755				3.0	25		50	4	1.8
1/19	0655				1.0	30		70	4	1.8
	1655				1.0	10		10	4	1.8
1/20	0655					40		40	11	4.9
	1655				1.0	45		30	4	1.8
1/21	0605				1.0	25		20	10	4.4
	1655				1.0	45		30	2	0.9
1/22	0655				1.0	15		10	12	5.3
	1555				1.0	25		10	5	2.2
1/23	0655				3.0	25			10	4.4
	1555				1.0	25			6	2.7
1/24	0655				2.0	30			8	3.5
	1555				2.0	10			5	2.2
1/25	0655				1.0	10			9	4.0

Table 3a. Experimental data on Group III cows - controls. Cow No. 2

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results - pCi/kg		Milk Sample Results - pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0700	10.0				15			26	11.5
1/14	0310					10			12	5.3
	1710	10.0			3.0	5			19	8.4
1/15	0700				2.0	25			17	7.5
	1700	4.5			2.0	20			17	7.5
1/16	0700				1.0	20			26	11.5
	1600	10.0			3.0	10			13	5.8
1/17	0700				1.0	20			24	10.6
	1600	10.0			1.0	20			15	6.6
1/18	0700				3.0	10			26	11.5
	1800	10.0			4.0	10			16	7.1
1/19	0700				2.0	35			15	6.6
	1700	9.1			1.0				19	8.4
1/20	0700				2.0	30			24	10.6
	1700	9.5			1.0	10			17	7.5
1/21	0700				2.0	10			24	10.6
	1700	9.5			2.0	25			13	5.8
1/22	0700				2.0				23	10.2
	1600	10.0			3.0	10			15	6.6
1/23	0700				2.0	35			22	9.7
	1600				1.0	30			16	7.1
1/24	0700					15			22	9.7
	1600				1.0	10			13	5.8
1/25	0700				2.0	10			27	12.0

Table 3b. Experimental data on Group III cows - controls. Cow No. 16

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0710	10.0				25			30	13.3
1/14	0320					15			10	4.4
	1720	10.0			1.0	5			18	8.0
1/15	0710				4.0	10			15	6.6
	1710	9.5			2.0	15			17	7.5
1/16	0710				2.0	10			24	10.6
	1610	10.0			1.0	5			11	4.9
1/17	0710				1.0	25			23	10.2
	1610	10.0			2.0	10			13	5.8
1/18	0710				4.0	10			23	10.2
	1810	10.0			1.0	5			13	5.8
1/19	0710				2.0	5			17	7.5
	1710	8.6			2.0	10			11	4.9
1/20	0710				1.0	5			25	11.1
	1710	9.5				15			13	5.8
1/21	0710				2.0	5			24	10.6
	1710	8.2			2.0	20			11	4.9
1/22	0710				2.0	30			24	10.6
	1610	8.6			2.0	20			14	6.2
1/23	0710					15			21	9.3
	1610				1.0	35			11	4.9
1/24	0710				1.0				26	11.5
	1610				1.0	5			13	5.8
1/25	0710				6.0	10			20	8.9

Table 3c. Experimental data on Group III cows - controls. Cow No. 22

Date	Milking Time	Kg. Hay Consumed	Hay Sample Results-pCi/kg		Milk Sample Results-pCi/l				Milk Produced	
			^{133}I	^{131}I	^{90}Sr	^{137}Cs	^{133}I	^{131}I	Lbs.	Liters
1/13	0720	10.0				10			24	10.6
1/14	0330					5			15	6.6
	1730	10.0			2.0	30			14	6.2
1/15	0720				3.0	10			18	8.0
	1720	8.2			4.0	20			11	4.9
1/16	0720				1.0	15			26	11.5
	1620	10.0			6.0	25			10	4.5
1/17	0720				1.0	15			21	9.3
	1620	9.5			4.0	25			12	5.3
1/18	0720				3.0	10			25	11.1
	1820	10.0			5.0	15			12	5.3
1/19	0720				4.0	45			16	7.1
	1720	10.0			2.0	15			15	6.6
1/20	0720				5.0				25	11.1
	1720	9.1			6.0				12	5,3
1/21	0720				3.0	35			26	11.5
	1720	9.1			2.0	15			11	4.9
1/22	0720				3.0	20			26	11.5
	1620	8.6			4.0	30			11	4.9
1/23	0720				3.0	15			25	11.1
	1620				3.0	30			14	6.2
1/24	0720				3.0	20			24	10.6
	1620				3.0				14	6.2
1/25	0720				3.0	5			26	11.5

Table 4. Weighted average data for K, Ca, ^{90}Sr, and ^{137}C, in Group I milk.*

Date	g/liter		pCi/liter	
	K	Ca	^{90}Sr	^{137}Cs
1/13/65	1.48±0.08	1.15±0.02	--	18.7±6.2
1/14/65	1.51±0.16	1.21±0.05	--	36.8±6.3
1/15/65	1.40±0.15	1.23±0.06	3.2±0.5	28.0±8.0
1/16/65	1.36±0.20	1.17±0.07	3.1±0.4	25.8±7.0
1/17/65	1.40±0.12	1.18±0.06	2.0±0.5	29.2±5.3
1/18/65	1.38±0.13	1.14±0.12	2.4±1.9	26.6±6.3
1/19/65	1.48±0.10	1.14±0.07	2.9±1.0	26.9±4.1
1/20/65	1.60±0.12	1.12±0.08	3.7±4.1	32.8±3.8
1/21/65	1.46±0.05	1.13±0.10	2.7±1.6	27.4±2.3
1/22/65	1.42±0.08	1.19±0.10	2.5±1.0	27.6±3.2
1/23/65	1.49±0.10	1.13±0.06	2.5±1.0	24.2±7.6
1/24/65	1.48±0.17	1.14±0.03	2.8±1.1	21.6±3.6

* ± 1σ

Table 5. Weighted average data for K, Ca, ^{90}Sr, and ^{137}Cs in Group II milk.*

	g/liter		pCi/liter	
Date	K	Ca	^{90}Sr	^{137}Cs
1/14/65	1.46±0.15	1.16±0.07	1.9±0.8	32.8±7.6
1/15/65	1.40±0.18	1.13±0.04	3.3±1.4	31.0±4.6
1/16/65	1.36±0.19	1.18±0.05	3.7±1.0	34.8±8.7
1/17/65	1.40±0.09	1.16±0.04	2.9±1.7	20.9±5.4
1/18/65	1.38±0.04	1.09±0.11	3.2±1.1	25.0±8.7
1/19/65	1.51±0.08	1.15±0.07	3.9±2.1	28.6±7.8
1/20/65	1.60±0.15	1.11±0.06	3.8±3.4	23.2±9.5
1/21/65	1.53±0.15	1.10±0.04	3.2±2.1	18.2±7.6
1/22/65	1.46±0.15	1.14±0.08	3.6±2.3	24.8±10.8
1/23/65	1.53±0.08	1.11±0.14	3.1±1.8	22.8±2.9
1/24/65	1.44±0.11	1.10±0.06	2.3±0.6	17.8±9.4

*$\pm 1\sigma$

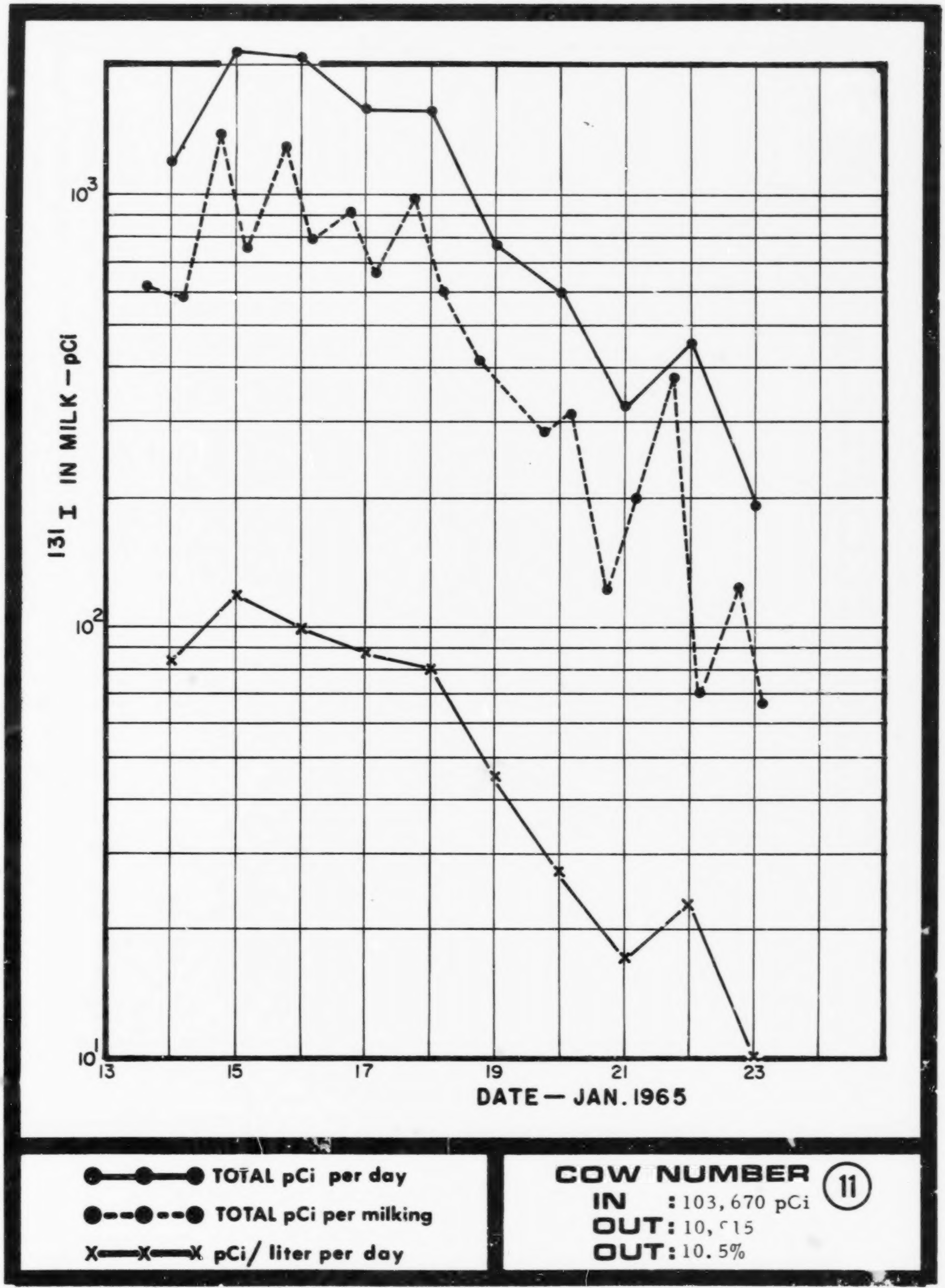

Figure 1a. ^{131}I milk data for cow No. 11

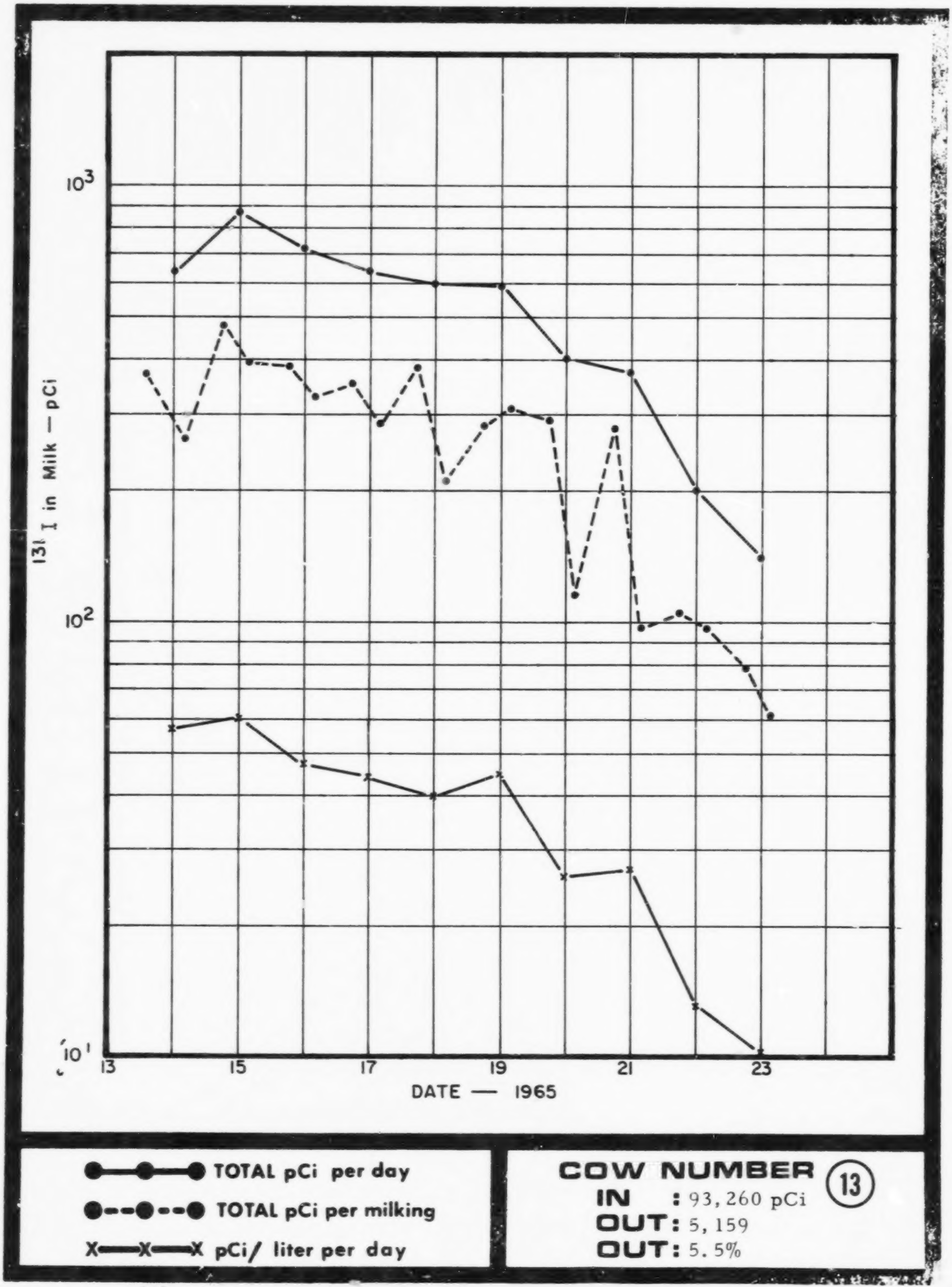

Figure 1b. ^{131}I milk data for cow No. 13

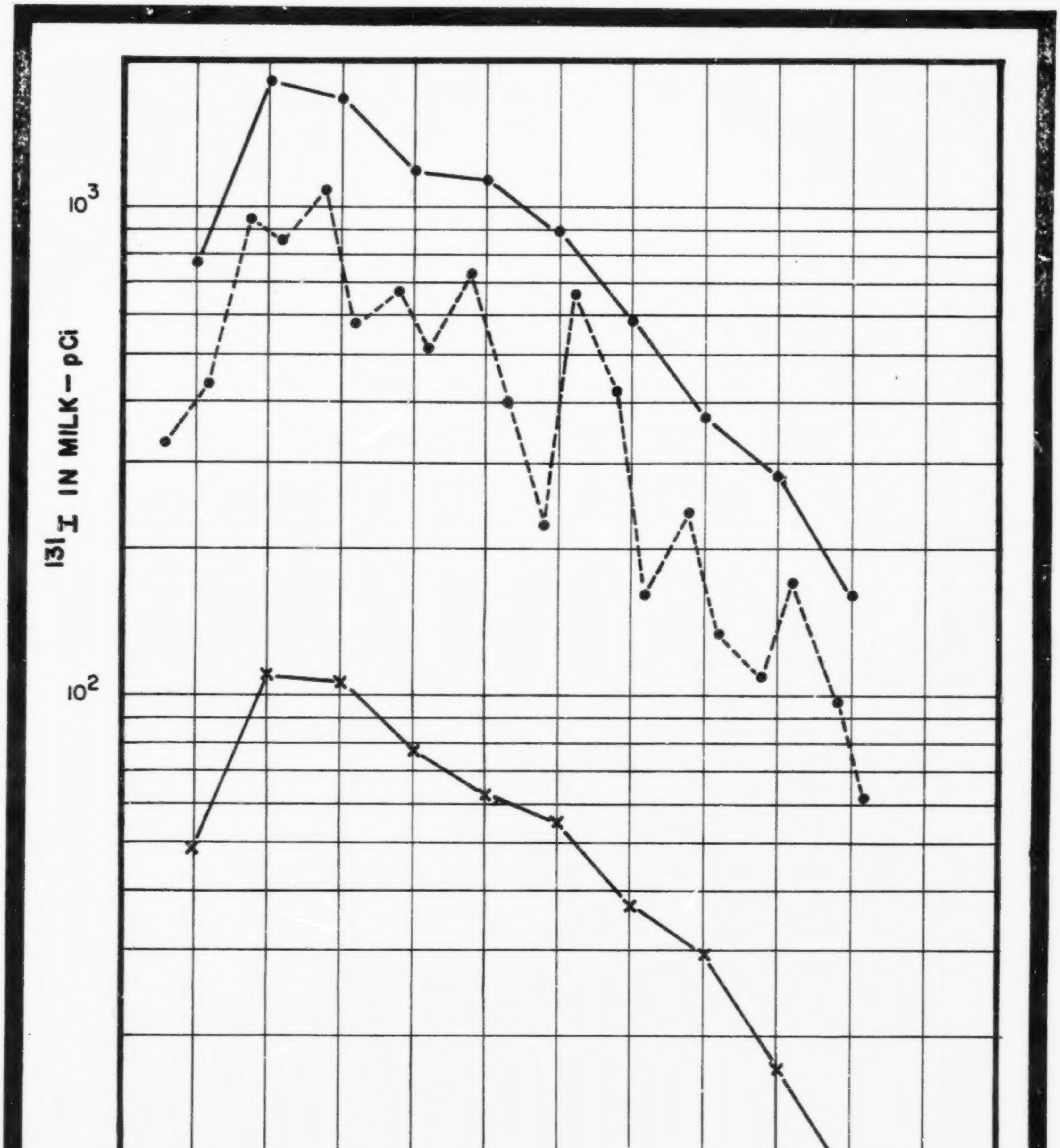

Figure 1c. ^{131}I milk data for cow No. 21

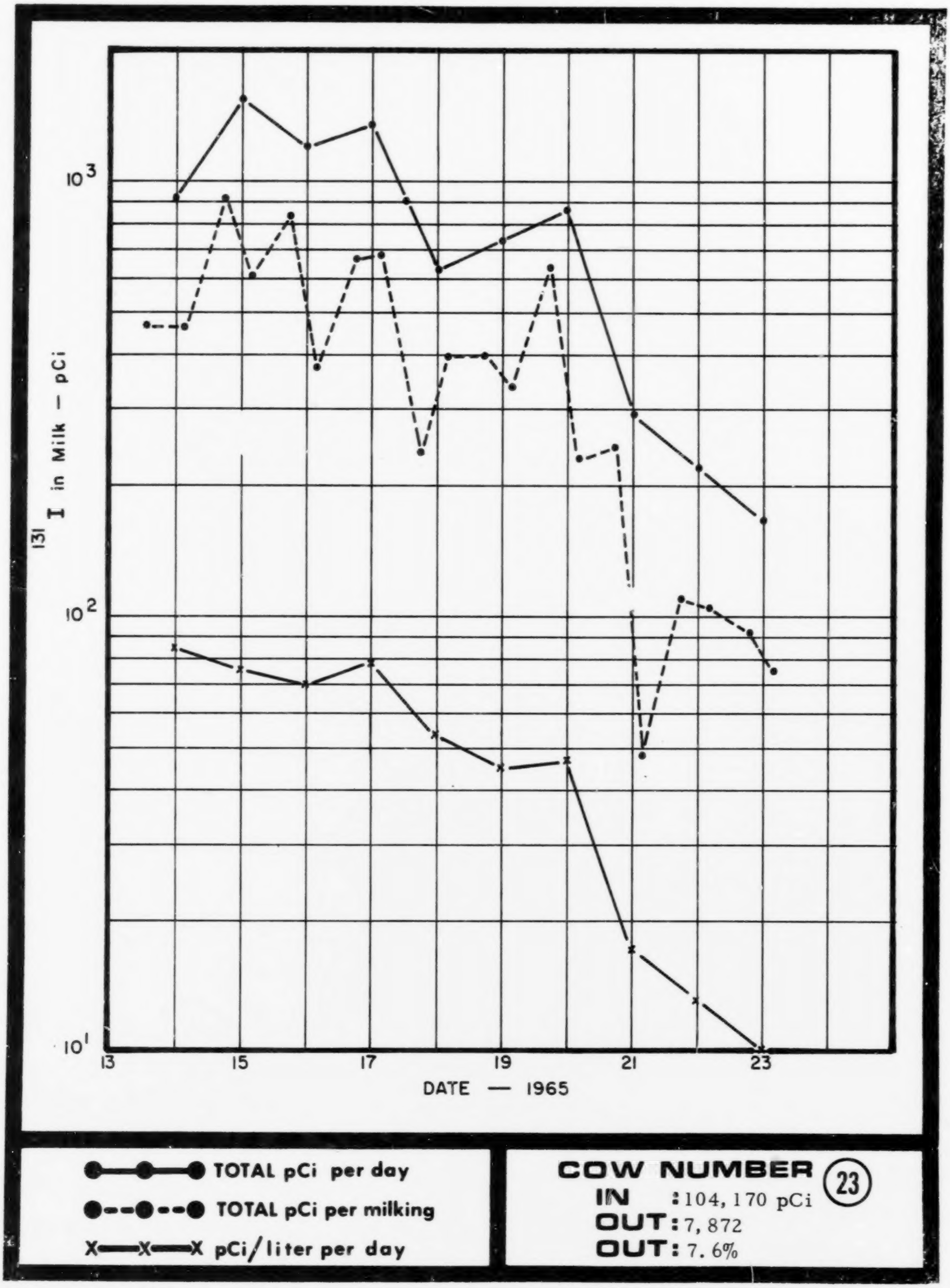

Figure 1d. ^{131}I milk data for cow No. 23

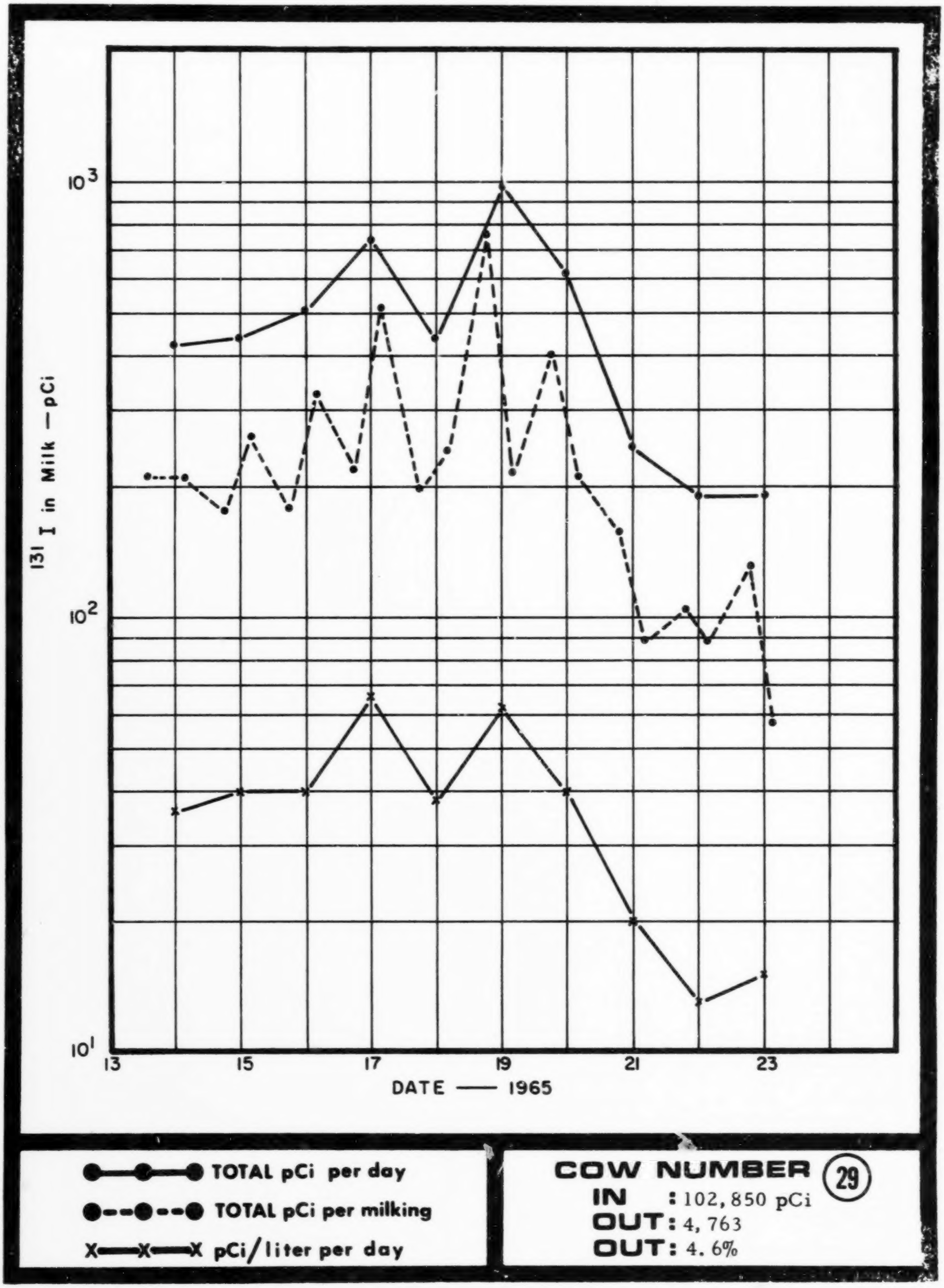

Figure 1e. ^{131}I milk data for cow No. 29

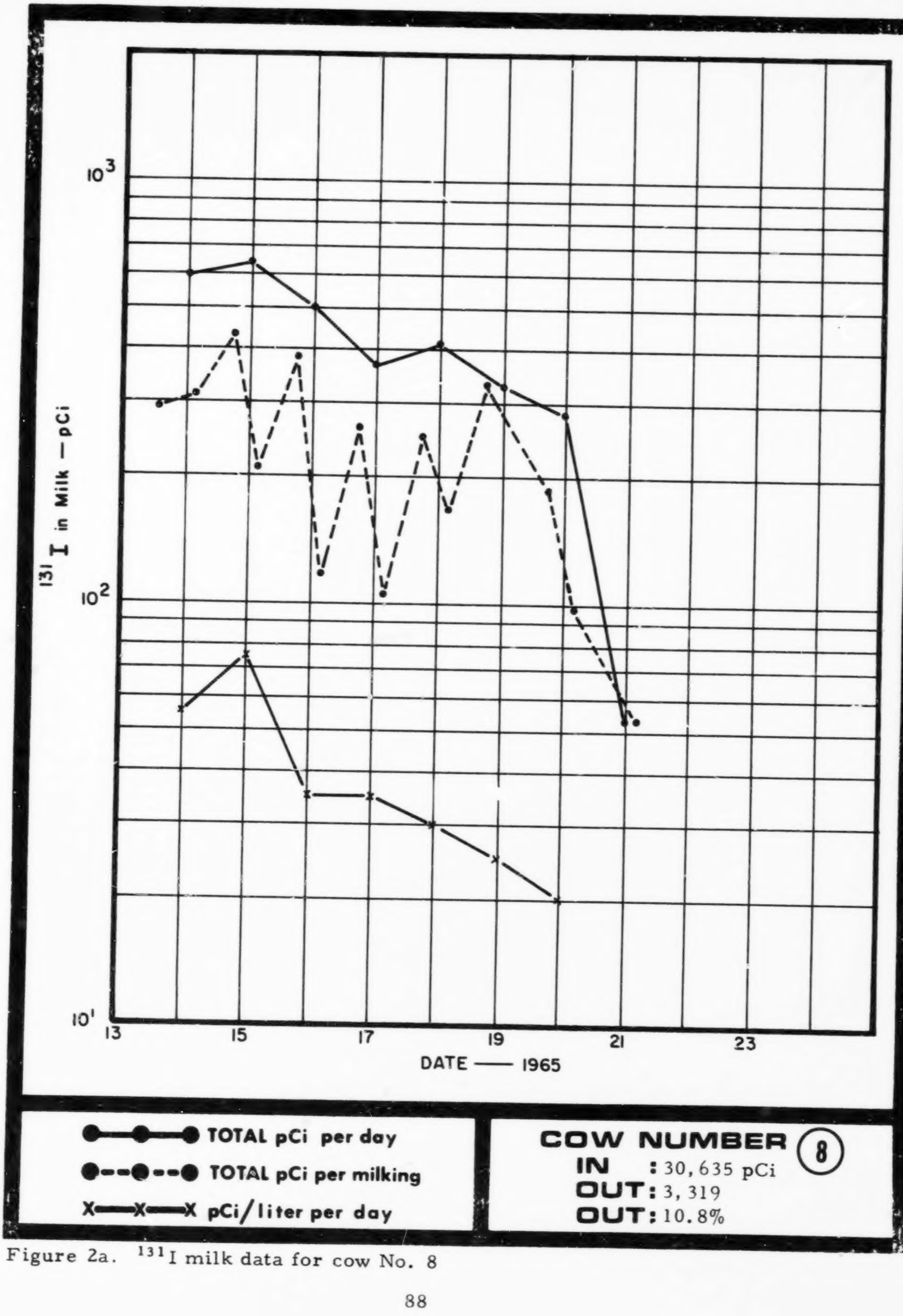

Figure 2a. ^{131}I milk data for cow No. 8

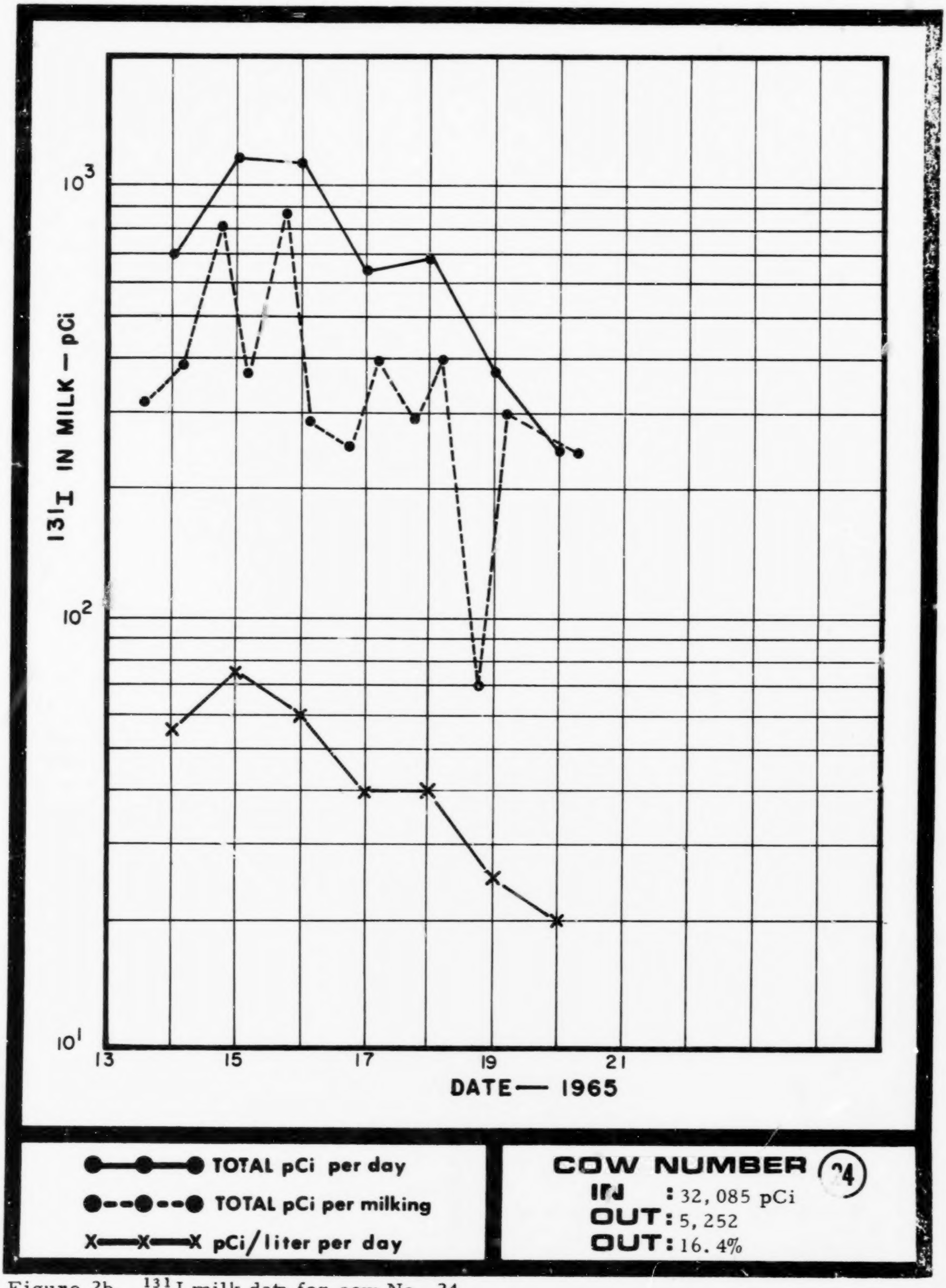

Figure 2b. ^{131}I milk data for cow No. 24

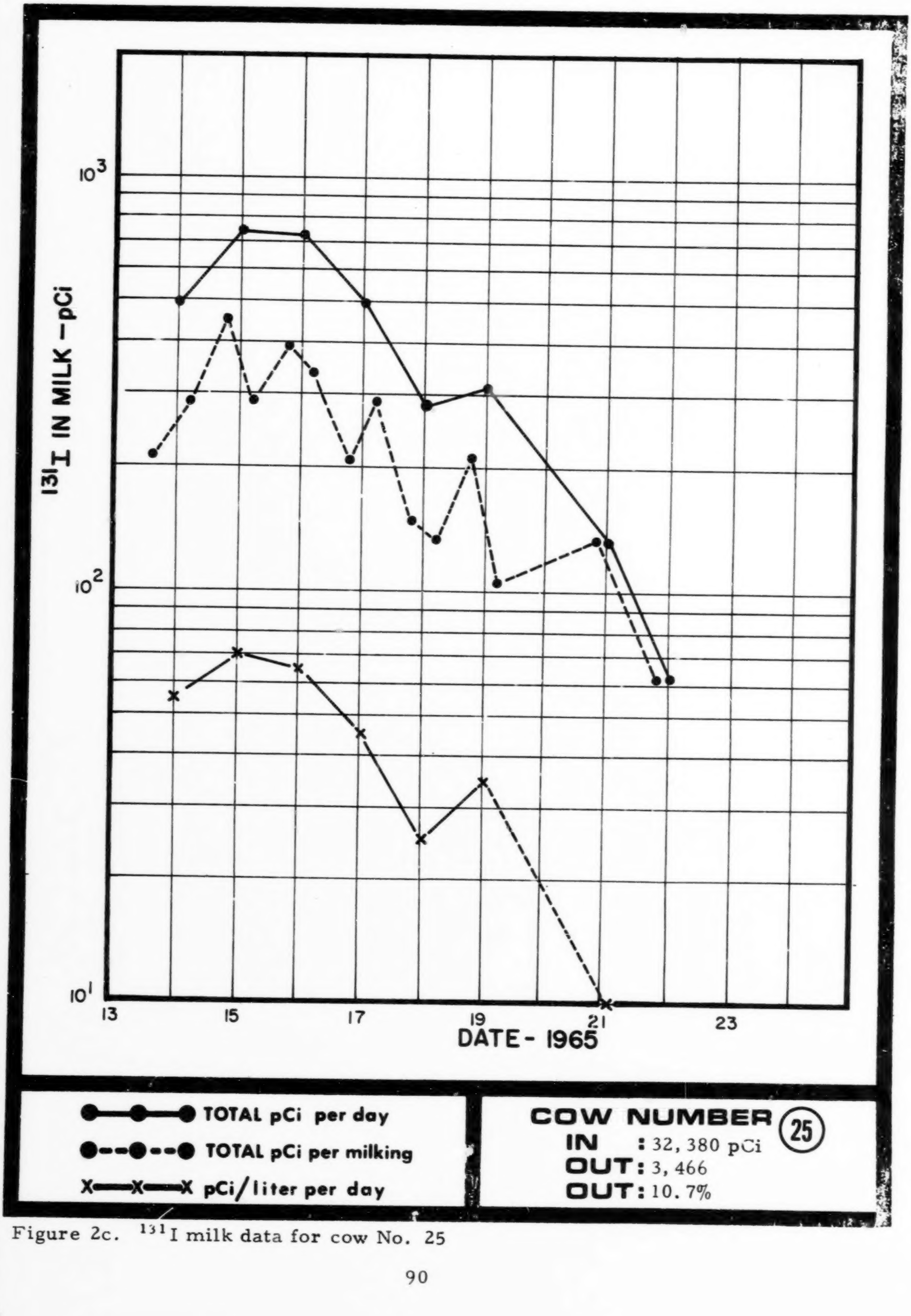

Figure 2c. ^{131}I milk data for cow No. 25

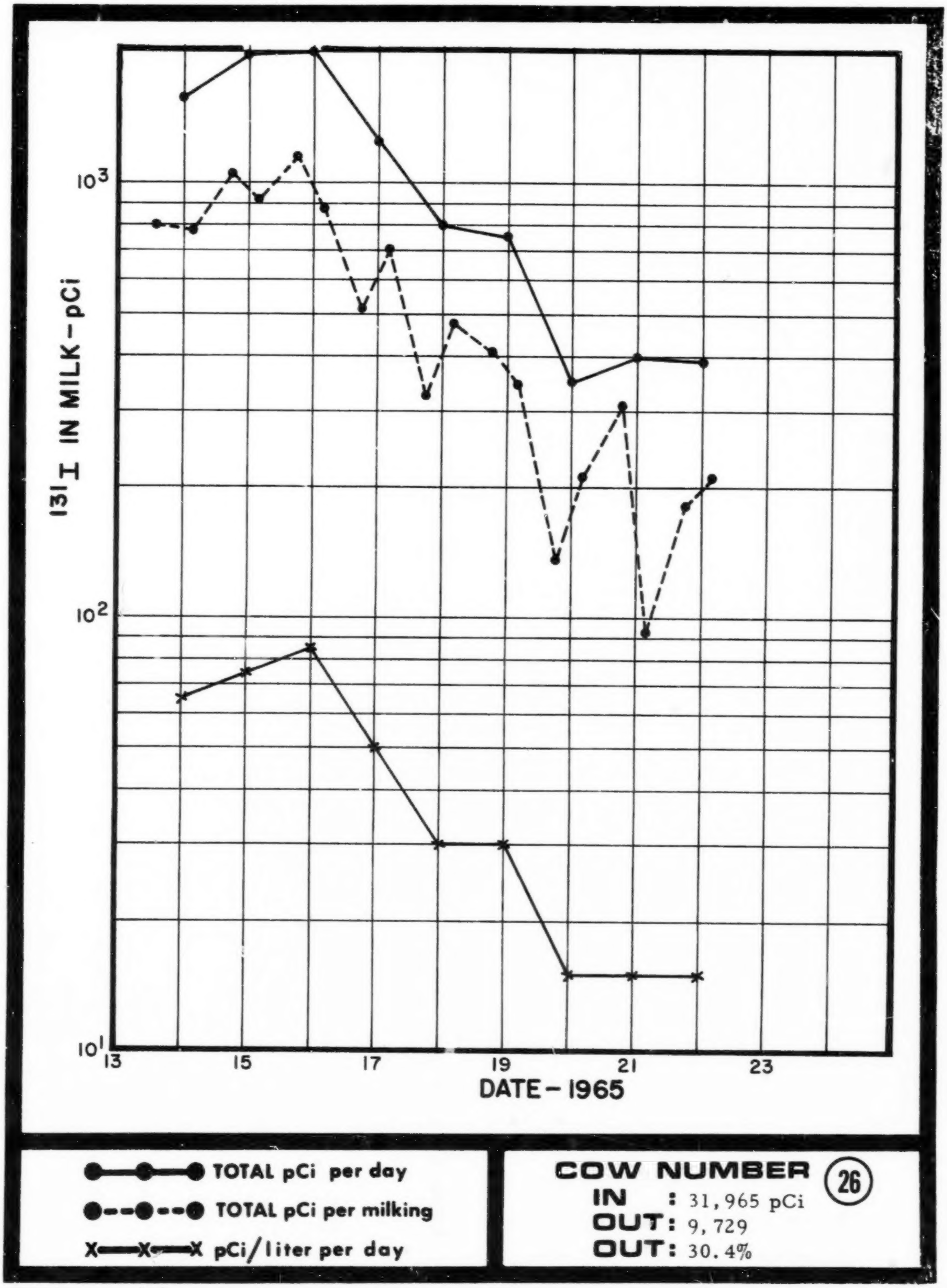

Figure 2d. ^{131}I milk data for cow No. 26

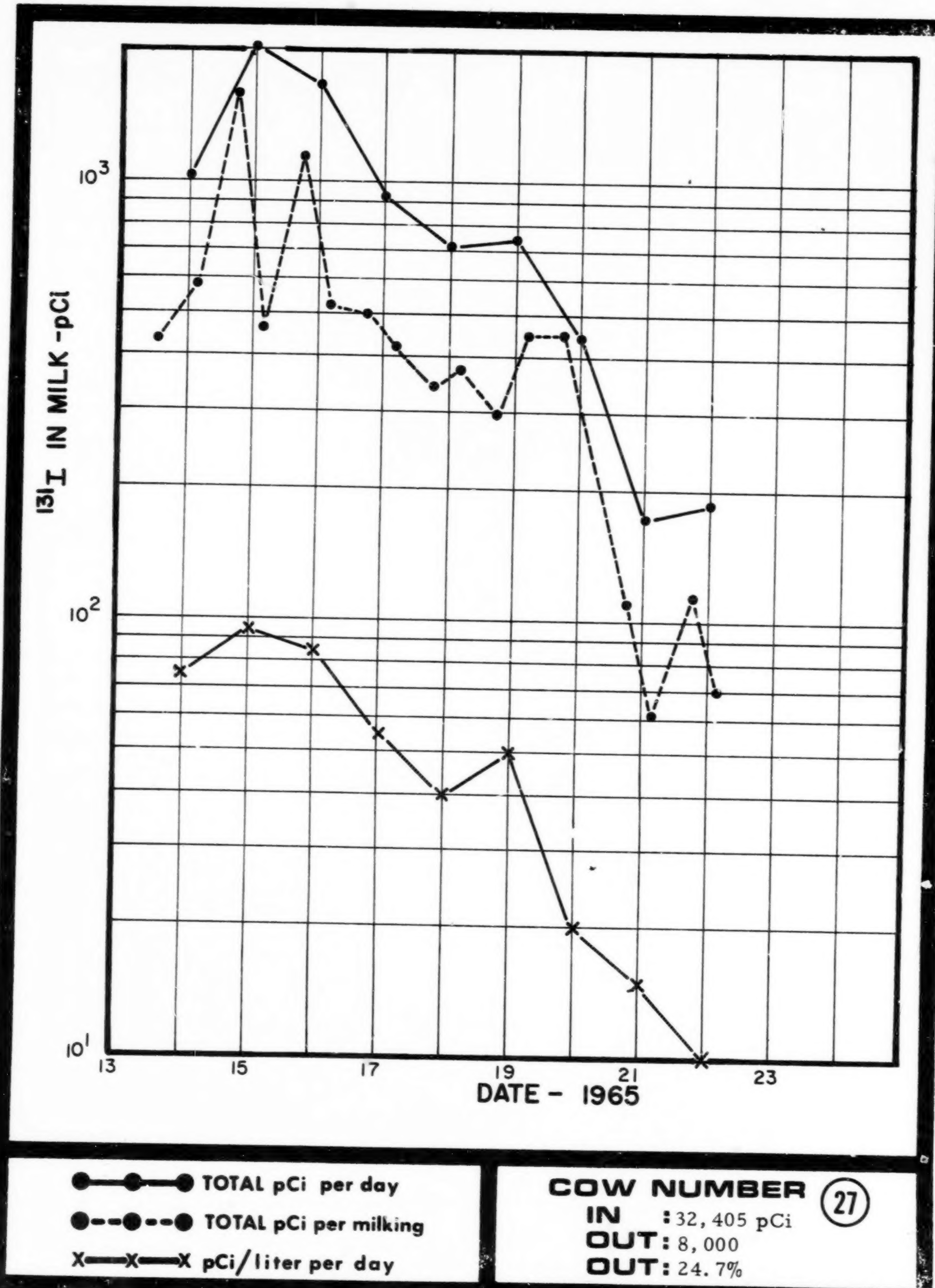

Figure 2e. ^{131}I milk data for cow No. 27